US007952697B2

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Fedele et al.

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(45) **Date of Patent: May 31, 2011**

(54) **COFFEE REFRACTOMETER METHOD AND APPARATUS**

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(73) Assignee: **Voice Systems Technology, Inc.**, Harvard, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 147 days.

(21) Appl. No.: **12/247,232**

(22) Filed: **Oct. 8, 2008**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
G01N 21/41 (2006.01)

(52) **U.S. Cl.** **356/134**

(58) **Field of Classification Search** 356/134
See application file for complete search history.

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Primary Examiner — Roy Punnoose
(74) *Attorney, Agent, or Firm* — Mark P Kahler

(57) **ABSTRACT**

A coffee refractometer includes a prism that receives a brewed coffee sample, thus forming a prism-sample interface. A processor or microcontroller controls a light source to provide incident light to the prism-sample interface. The prism-sample interface refracts light toward a photodetector. A temperature sensor provides temperature information to the processor. The refractometer includes a memory store that stores a TDS formula that expresses the TDS of brewed coffee as a function of the index of refraction (n_s) of brewed coffee and the temperature of brewed coffee. The processor determines the TDS of the brewed coffee sample by accessing the TDS formula in the memory store and employing the determined index of refraction (n_s) of the brewed coffee sample to find the TDS from the TDS formula. The refractometer displays the resultant TDS % on a display of the refractometer and/or transmits such information to an information handling system.

16 Claims, 30 Drawing Sheets

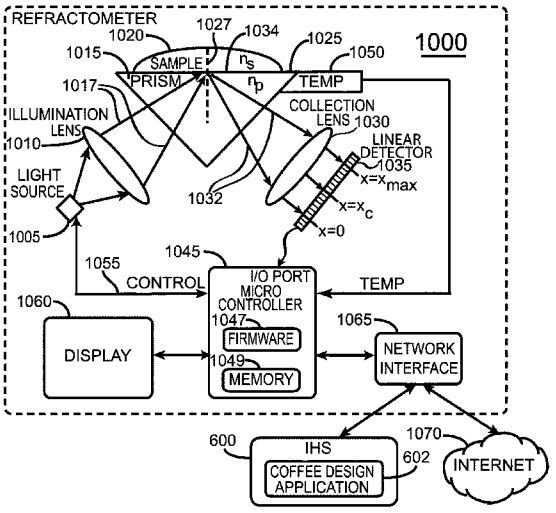

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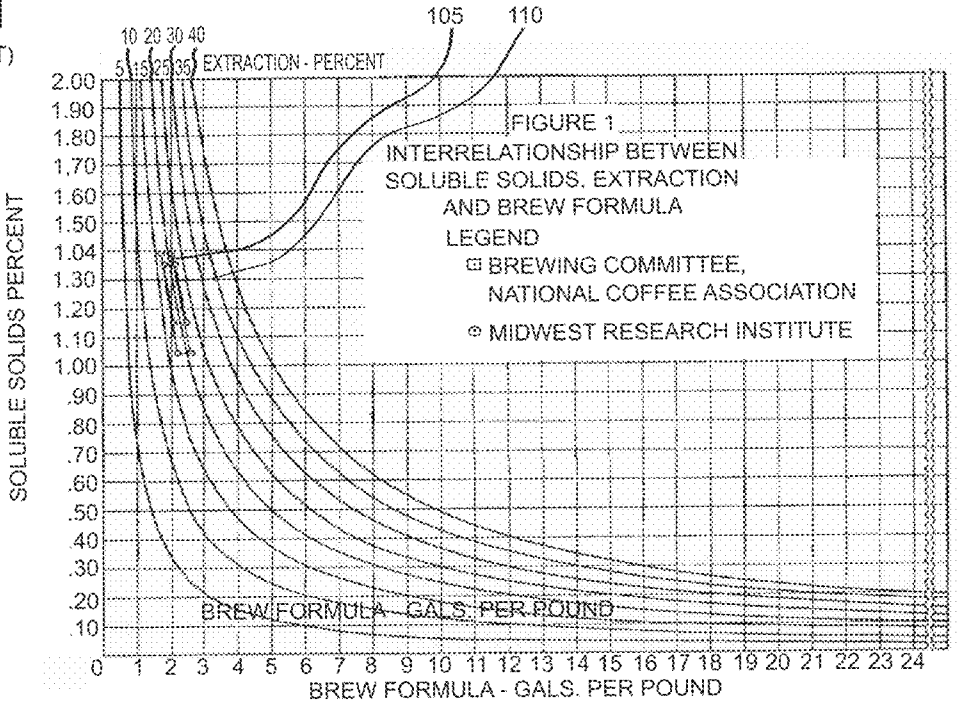
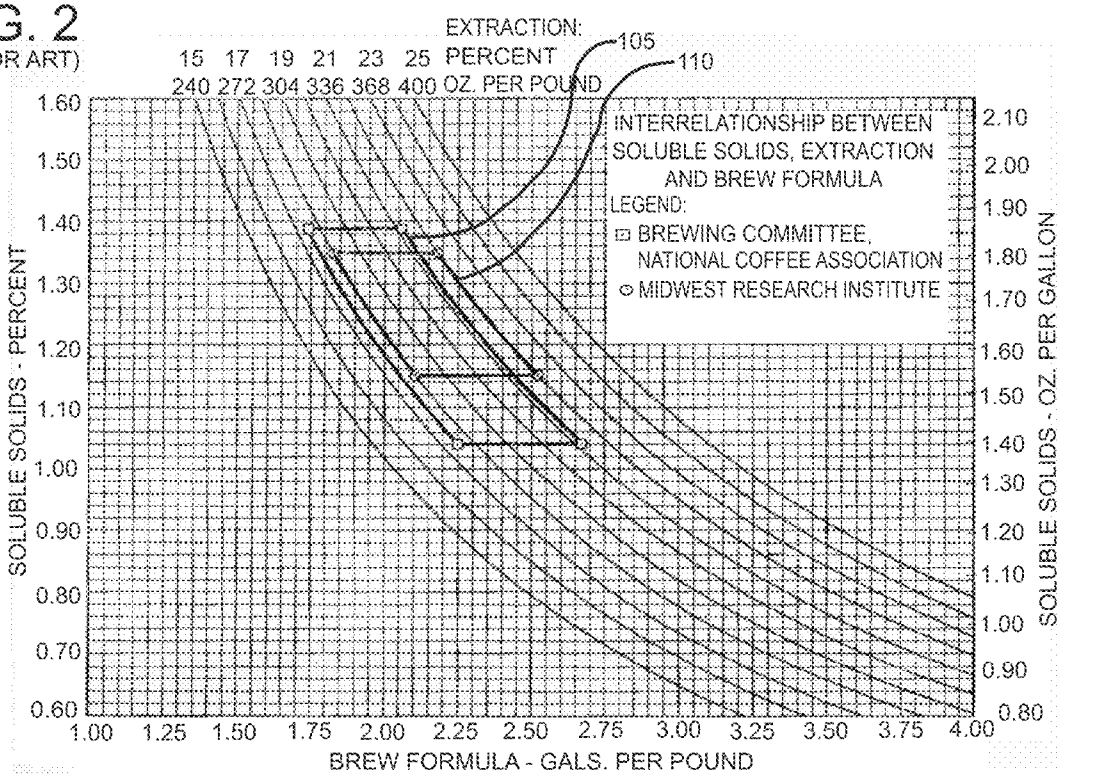
FIG. 1
(PRIOR ART)



(CBC Publication No. 27, 1969, p12.)

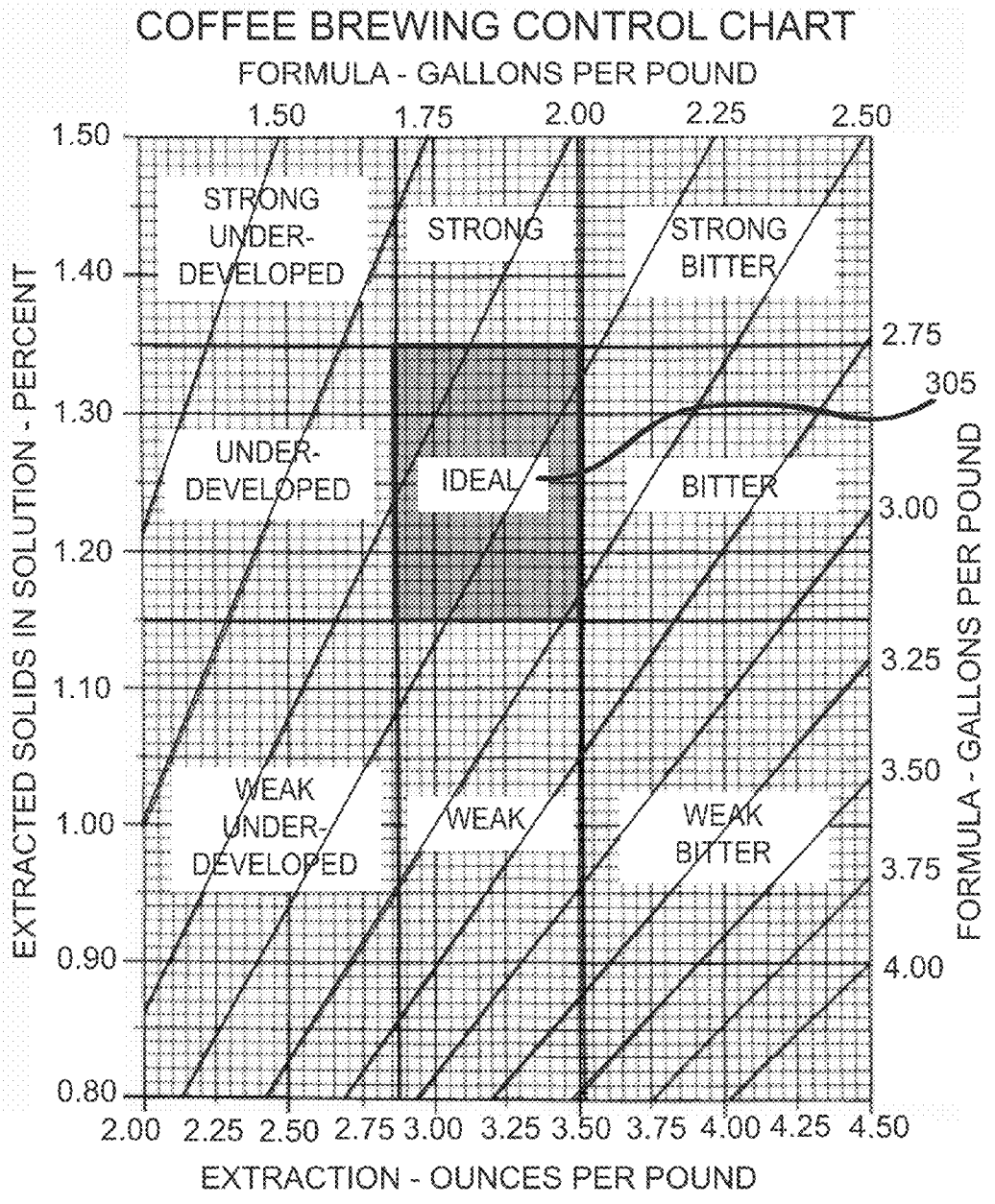
FIG. 2
(PRIOR ART)



(CBC Publication No. 27, 1969, p13.)

FIG. 3

(PRIOR ART)



(CBC Publication No. 43, 1959)

FIG. 4A

(PRIOR ART)

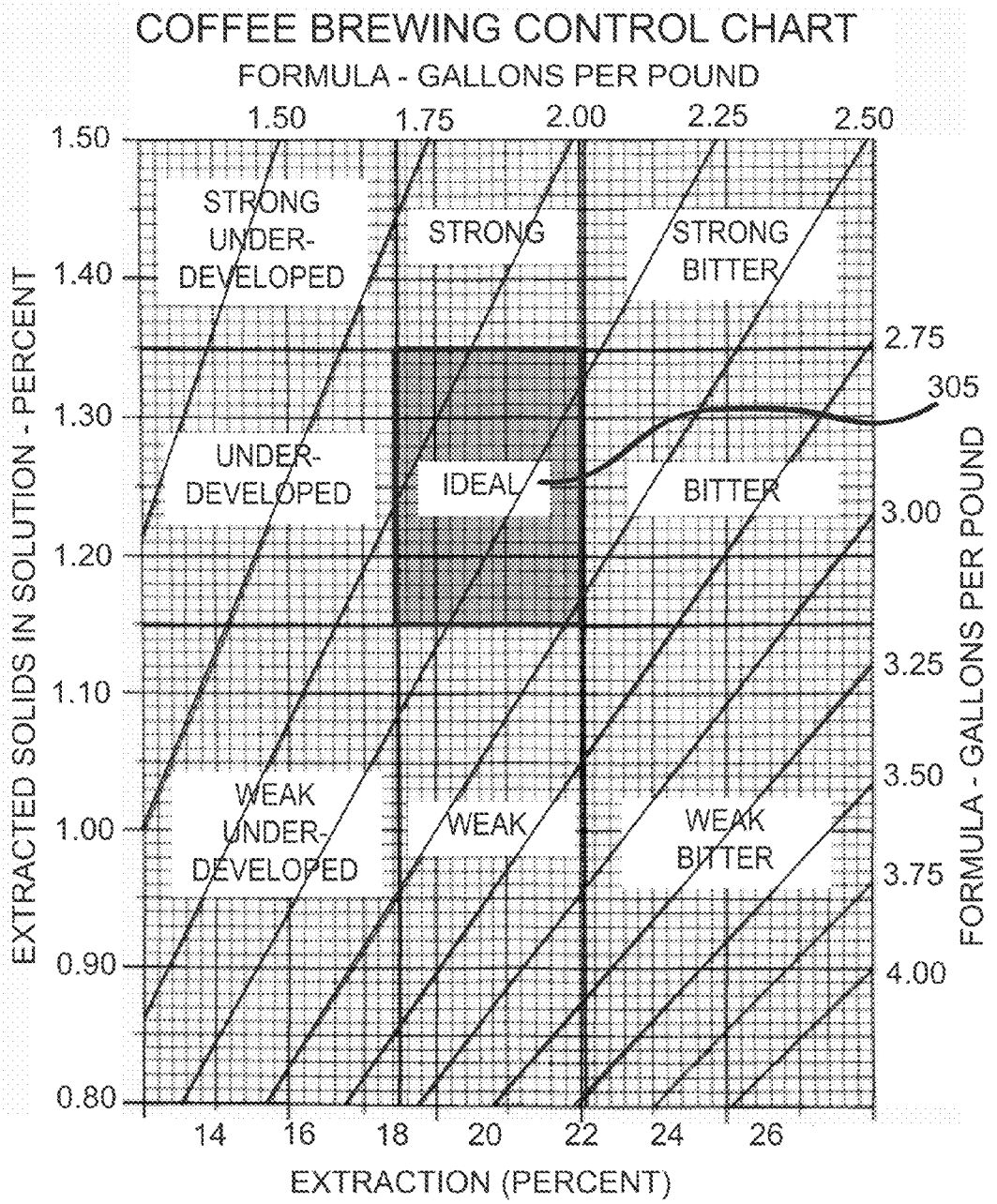


FIG. 4B
(PRIOR ART)

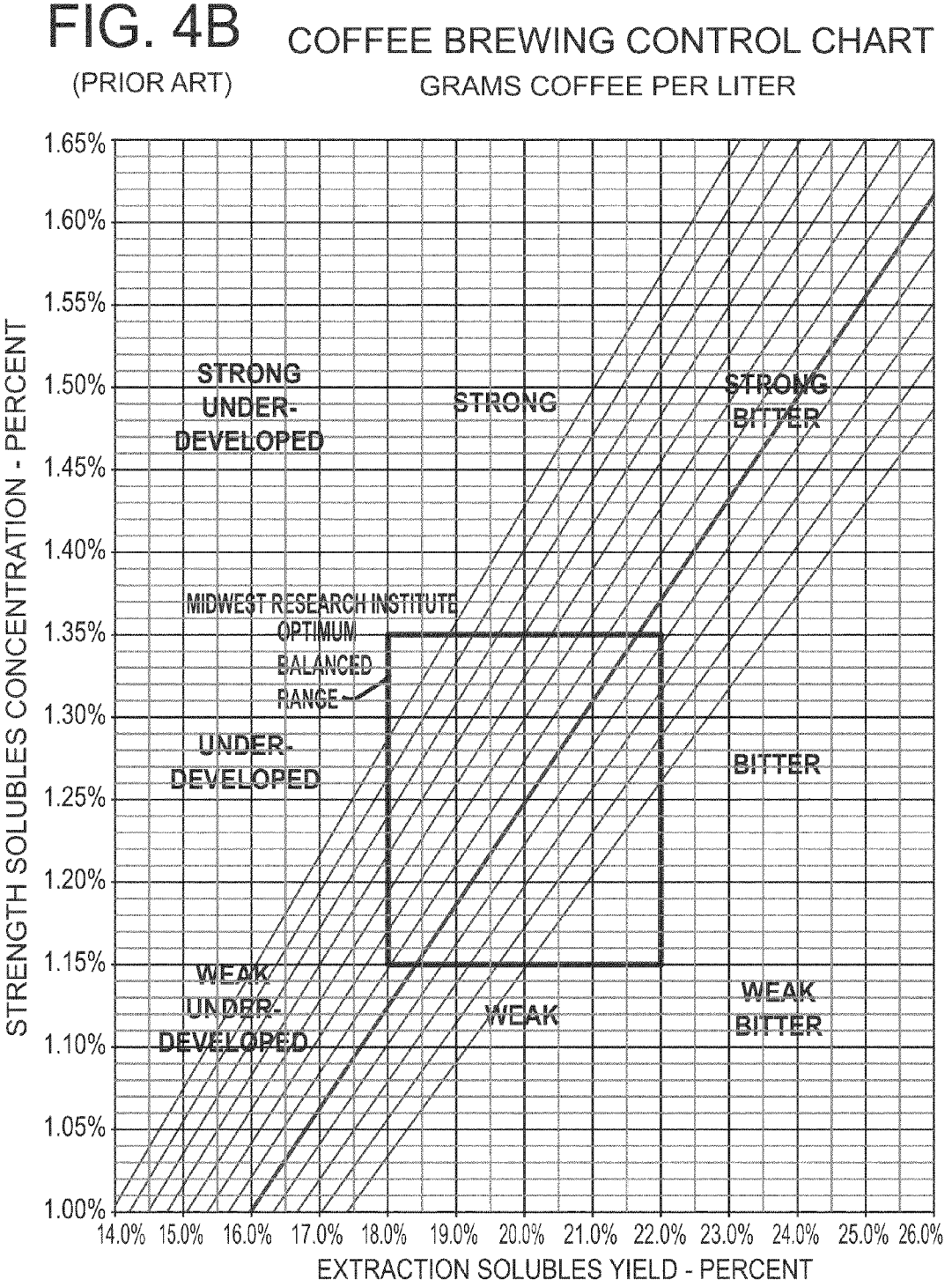


FIG. 4C
(PRIOR ART)

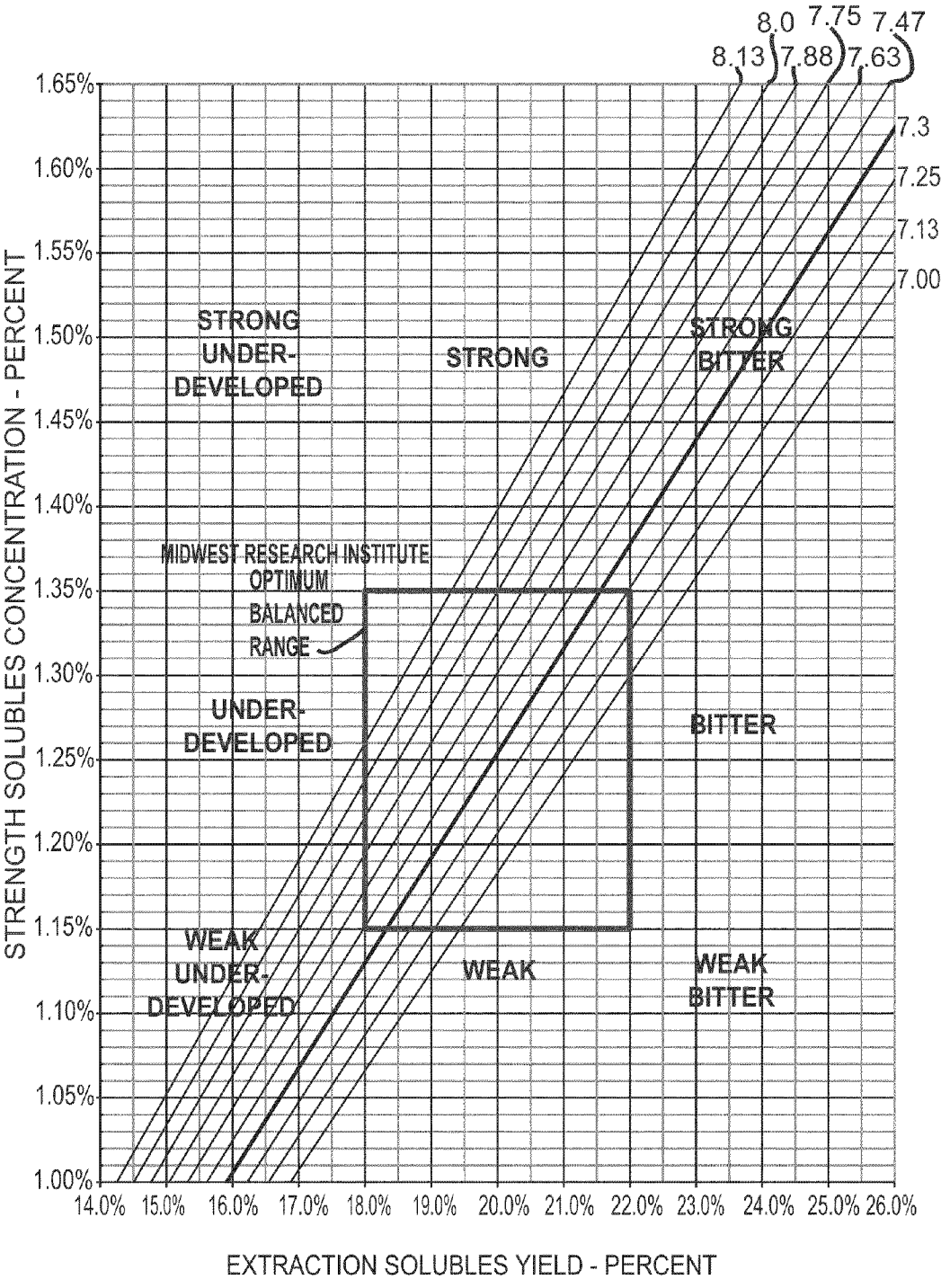


FIG. 4D (PRIOR ART)

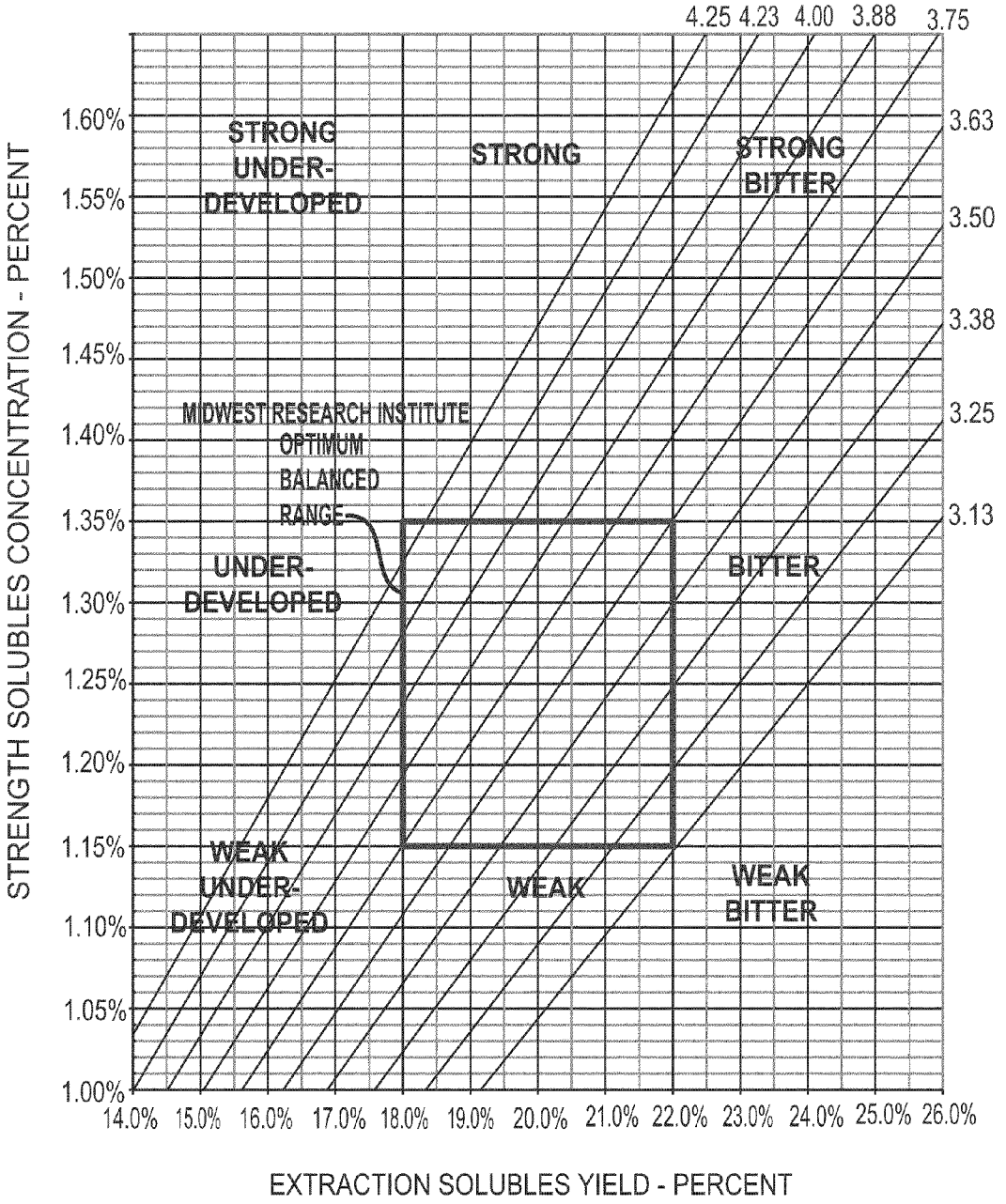


FIG. 4E
(PRIOR ART)

COFFEE BREWING CONTROL CHART
OUNCES COFFEE PER 1.0 GALLON WATER

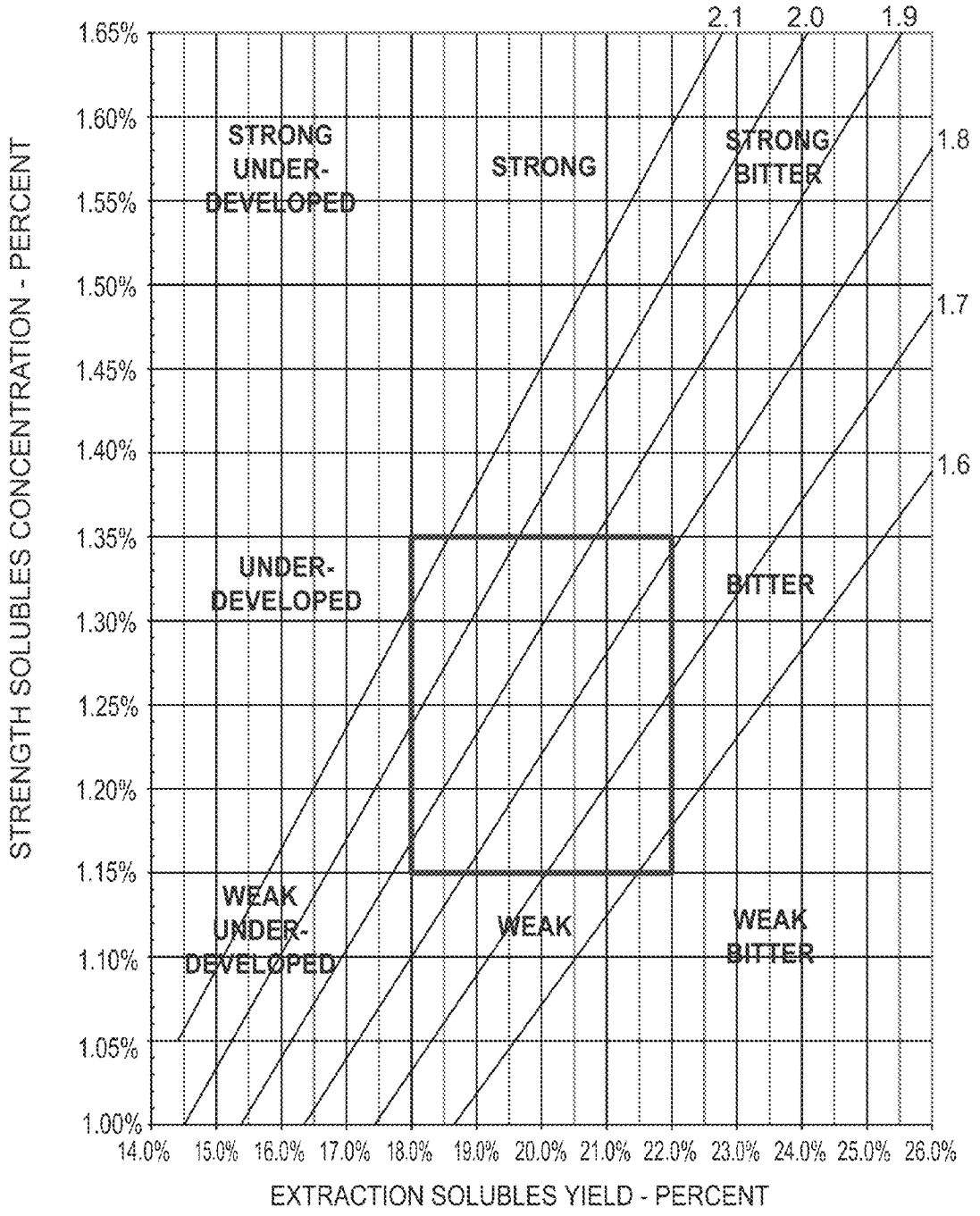


FIG. 5

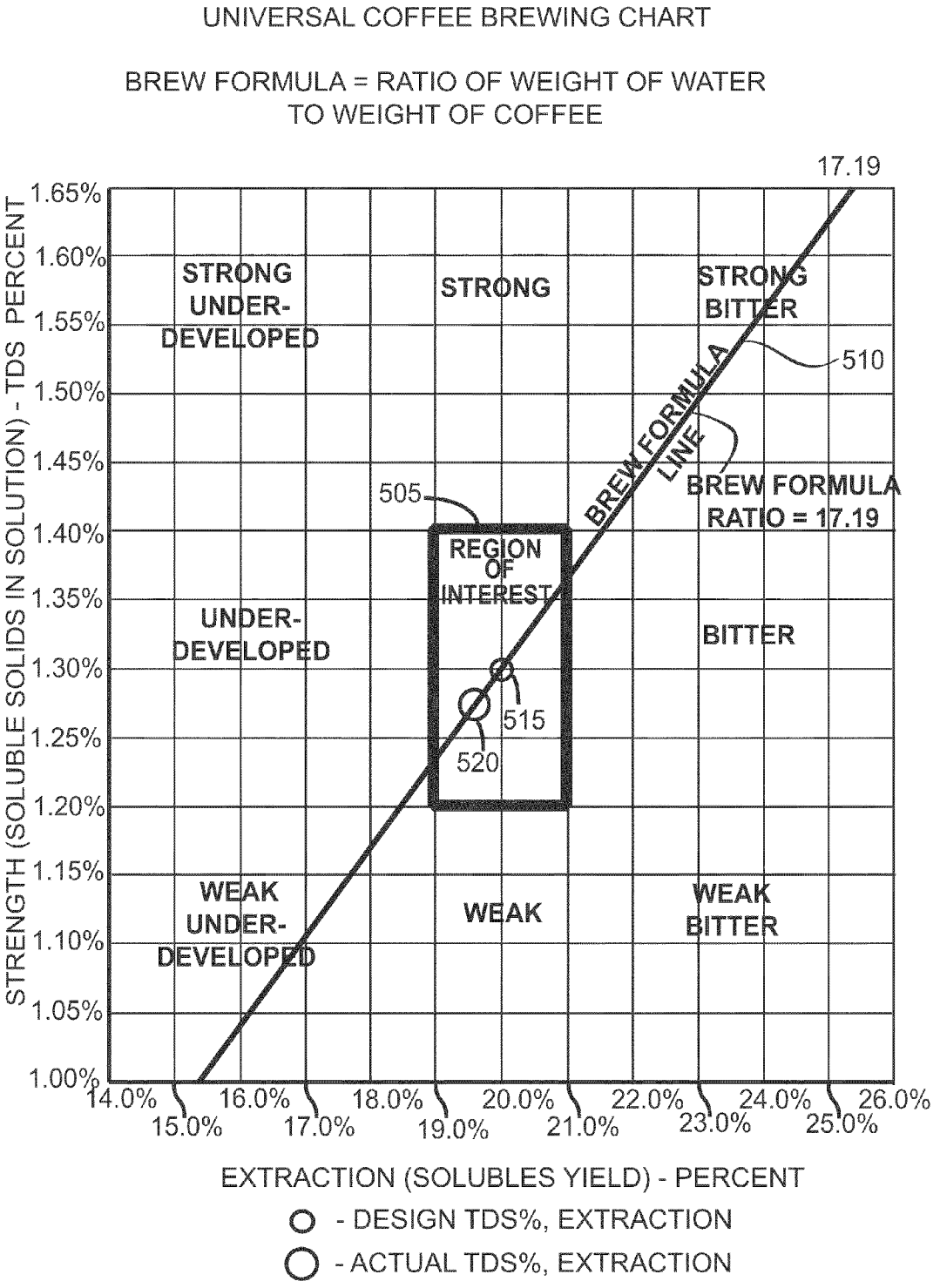

UNIVERSAL COFFEE BREWING CHART
BREW FORMULA = RATIO OF WEIGHT OF WATER TO WEIGHT OF COFFEE
17.19
STRONG UNDER-DEVELOPED
STRONG
STRONG BITTER
510
BREW FORMULA LINE
BREW FORMULA RATIO = 17.19
505
REGION OF INTEREST
UNDER-DEVELOPED
BITTER
515
520
WEAK UNDER-DEVELOPED
WEAK
WEAK BITTER
STRENGTH (SOLUBLE SOLIDS IN SOLUTION) - TDS PERCENT
1.65%
1.60%
1.55%
1.50%
1.45%
1.40%
1.35%
1.30%
1.25%
1.20%
1.15%
1.10%
1.05%
1.00%
14.0%
15.0%
16.0%
17.0%
18.0%
19.0%
20.0%
21.0%
22.0%
23.0%
24.0%
25.0%
26.0%
EXTRACTION (SOLUBLES YIELD) - PERCENT
- DESIGN TDS%, EXTRACTION
- ACTUAL TDS%, EXTRACTION

FIG. 6A

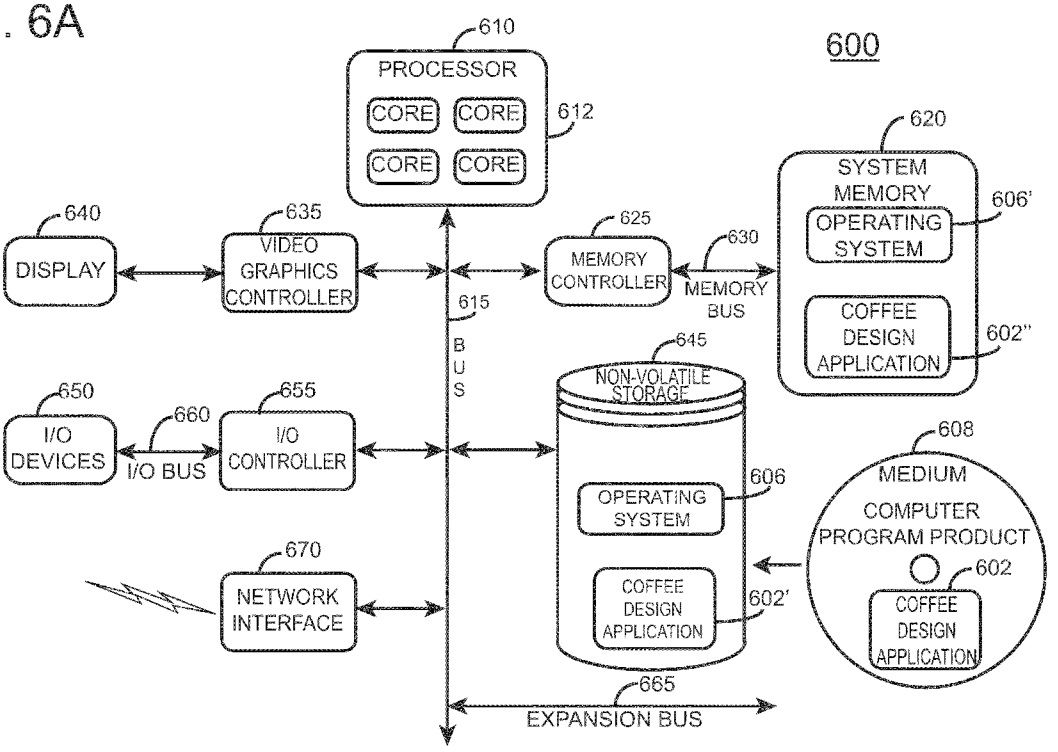

600
610
PROCESSOR
CORE
CORE
CORE
CORE
612
620
SYSTEM MEMORY
606'
OPERATING SYSTEM
COFFEE DESIGN APPLICATION
602"
640
DISPLAY
635
VIDEO GRAPHICS CONTROLLER
625
MEMORY CONTROLLER
630
MEMORY BUS
615
BUS
645
NON-VOLATILE STORAGE
650
I/O DEVICES
660
I/O BUS
655
I/O CONTROLLER
606
OPERATING SYSTEM
608
MEDIUM
COMPUTER PROGRAM PRODUCT
602
COFFEE DESIGN APPLICATION
670
NETWORK INTERFACE
COFFEE DESIGN APPLICATION
602'
665
EXPANSION BUS

FIG. 6B

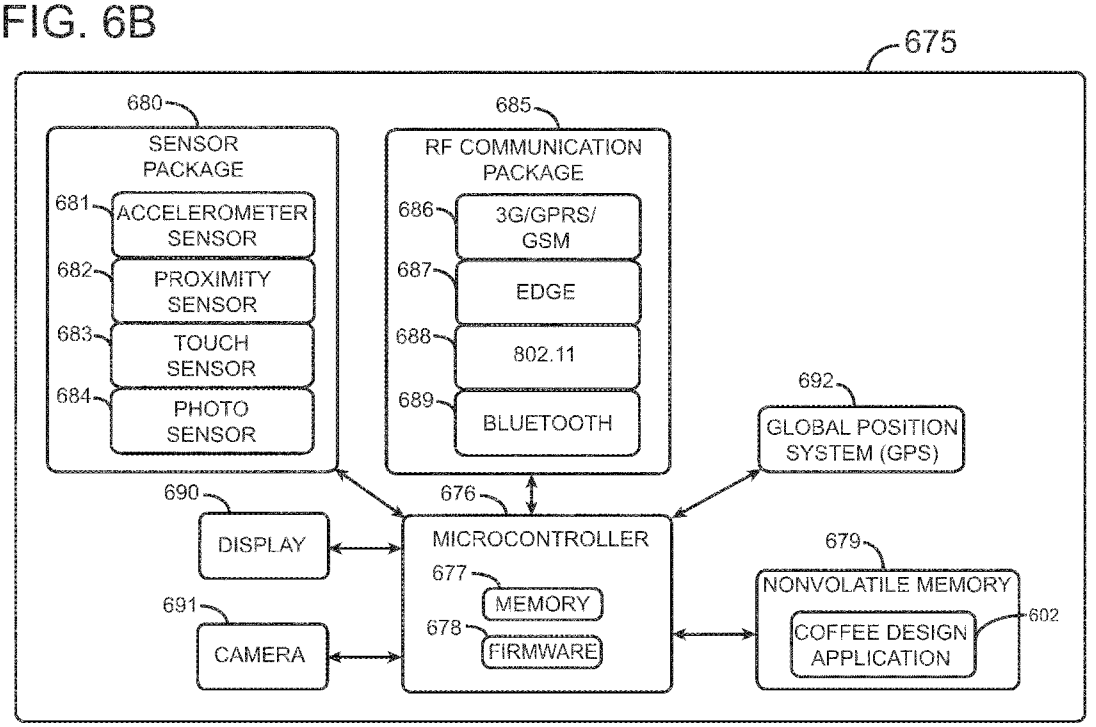

675
680
SENSOR PACKAGE
681
ACCELEROMETER SENSOR
682
PROXIMITY SENSOR
683
TOUCH SENSOR
684
PHOTO SENSOR
685
RF COMMUNICATION PACKAGE
686
3G/GPRS/ GSM
687
EDGE
688
802.11
689
BLUETOOTH
692
GLOBAL POSITION SYSTEM (GPS)
690
DISPLAY
676
MICROCONTROLLER
677
MEMORY
678
FIRMWARE
691
CAMERA
679
NONVOLATILE MEMORY
COFFEE DESIGN APPLICATION
602

FIG. 7A

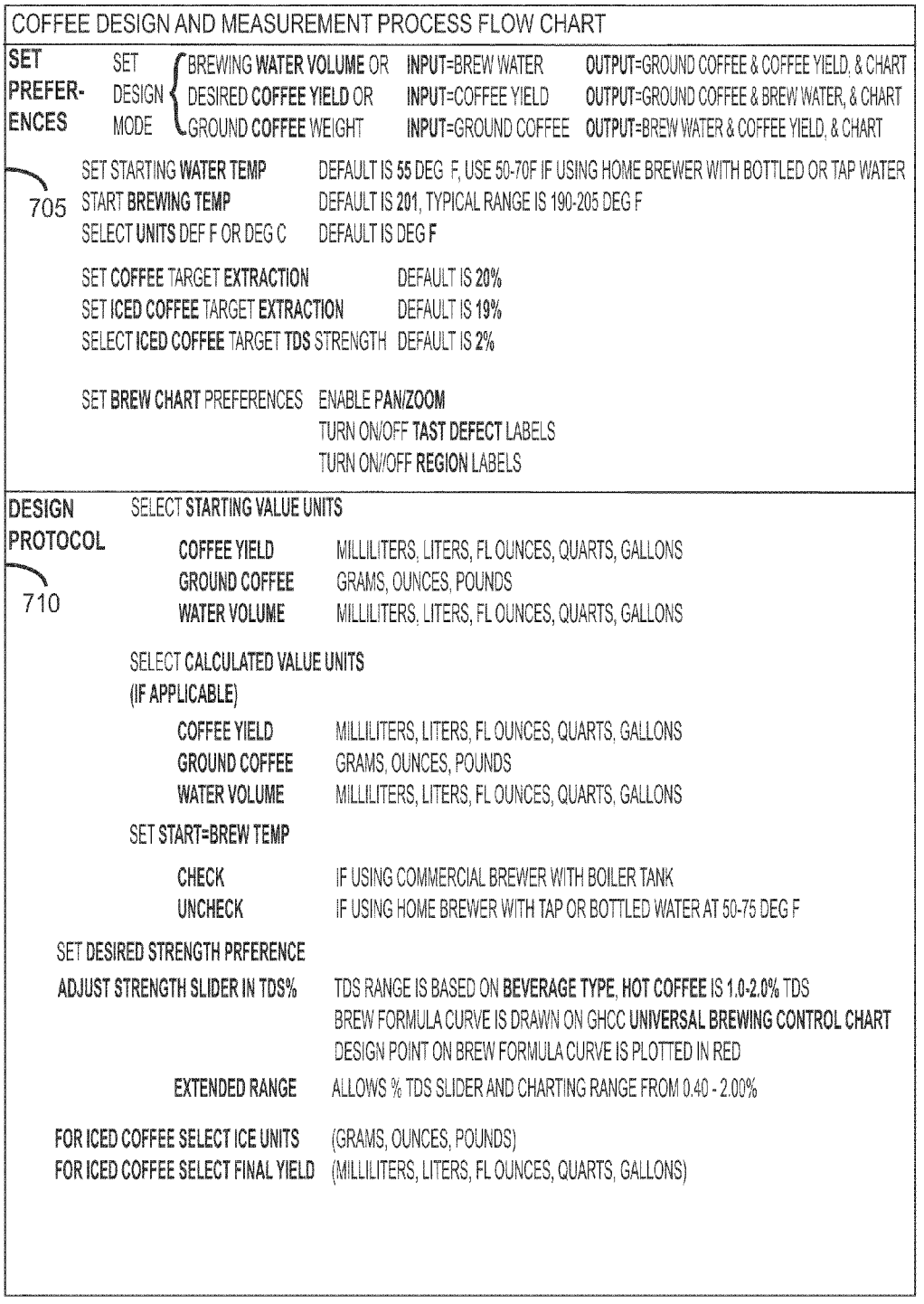

COFFEE DESIGN AND MEASUREMENT PROCESS FLOW CHART
SET PREFERENCES
SET DESIGN MODE
BREWING WATER VOLUME OR
DESIRED COFFEE YIELD OR
GROUND COFFEE WEIGHT
INPUT=BREW WATER
INPUT=COFFEE YIELD
INPUT=GROUND COFFEE
OUTPUT=GROUND COFFEE & COFFEE YIELD, & CHART
OUTPUT=GROUND COFFEE & BREW WATER, & CHART
OUTPUT=BREW WATER & COFFEE YIELD, & CHART
705
SET STARTING WATER TEMP
START BREWING TEMP
SELECT UNITS DEF F OR DEG C
DEFAULT IS 55 DEG F, USE 50-70F IF USING HOME BREWER WITH BOTTLED OR TAP WATER
DEFAULT IS 201, TYPICAL RANGE IS 190-205 DEG F
DEFAULT IS DEG F
SET COFFEE TARGET EXTRACTION
SET ICED COFFEE TARGET EXTRACTION
SELECT ICED COFFEE TARGET TDS STRENGTH
DEFAULT IS 20%
DEFAULT IS 19%
DEFAULT IS 2%
SET BREW CHART PREFERENCES
ENABLE PAN/ZOOM
TURN ON/OFF TAST DEFECT LABELS
TURN ON//OFF REGION LABELS
DESIGN PROTOCOL
710
SELECT STARTING VALUE UNITS
COFFEE YIELD
GROUND COFFEE
WATER VOLUME
MILLILITERS, LITERS, FL OUNCES, QUARTS, GALLONS
GRAMS, OUNCES, POUNDS
MILLILITERS, LITERS, FL OUNCES, QUARTS, GALLONS
SELECT CALCULATED VALUE UNITS
(IF APPLICABLE)
COFFEE YIELD
GROUND COFFEE
WATER VOLUME
MILLILITERS, LITERS, FL OUNCES, QUARTS, GALLONS
GRAMS, OUNCES, POUNDS
MILLILITERS, LITERS, FL OUNCES, QUARTS, GALLONS
SET START=BREW TEMP
CHECK
UNCHECK
IF USING COMMERCIAL BREWER WITH BOILER TANK
IF USING HOME BREWER WITH TAP OR BOTTLED WATER AT 50-75 DEG F
SET DESIRED STRENGTH PRFERENCE
ADJUST STRENGTH SLIDER IN TDS%
TDS RANGE IS BASED ON BEVERAGE TYPE, HOT COFFEE IS 1.0-2.0% TDS
BREW FORMULA CURVE IS DRAWN ON GHCC UNIVERSAL BREWING CONTROL CHART
DESIGN POINT ON BREW FORMULA CURVE IS PLOTTED IN RED
EXTENDED RANGE
ALLOWS % TDS SLIDER AND CHARTING RANGE FROM 0.40 - 2.00%
FOR ICED COFFEE SELECT ICE UNITS
FOR ICED COFFEE SELECT FINAL YIELD
(GRAMS, OUNCES, POUNDS)
(MILLILITERS, LITERS, FL OUNCES, QUARTS, GALLONS)

FIG. 7B

COFFEE DESIGN AND MEASUREMENT PROCESS FLOW CHART - CONTINUED		
TAKE TDS MEASUREMENT		
	CALIBRATE ATAGO **PAL-COFFEE** REFRACTOMETER	USING **DISTILLED WATER**, REFRACTOMETER & WATER SHOULD BE **AT 20-25 DEG C**
715	COOL 20 ML SAMPLE OF BREWED COFFEE`	TO 20-30 DEG C
	PLACE SAMPLE	IN COFFEE REFRACTOMETER
	ALLOW 1-2 MINUTES	FOR SAMPLE AND REFRACTOMETER TO REARCH SAME TEMP
	TAKE TDS READING	PRES **START** ON ATAGO **PAL-COFFEE** REFRACTOMETER
	ENTER TDS READING	IN THE DISSOLVED SOLIDS MEASURMENT BOX
	USING **PAL-COFFEE** REFRACTOMETER	**ENTER VALUE** IN % **TDS**
	IF USING **COFFEE CONDUCTIVITY METER**	**ENTER VALUE** IN **PPM** (ACCURACY MAY BE DEGRADED)
	IF USING **BRIX REFRACTOMETER**	**ENTER VALUE** IN % OR **DEG BRIX** (ACCURACY MAY BE DEGRATED)
		BREW RESULT IS PLOTED IN **BLUE**
		CORRECT BREW PROTOCOL IF NEEDED, BASED ON OVER OR UNDER EXTRACTION FROM TARGET
SAVE DATA	SAVE DATA	
	SAVE PLOT	
720	RECALL PREVIOUS COFFEE RECIPE	
	EMAIL DATA	
PRINT DATA	PRINT CHART	
	PRANT DATA	
725		
HELP INFO	EXTRACTMOJO USER MANUAL	ADOBE READER FORMAT IN PDF ONLINE FROM HELP MENU
	EXTRACTMOJO QUICKSTART GUIDE	ADOBE READER FORMAT IN PDF ONLINE FROM HELP MENU
730	EXTRACTMOJO LICENSE AGREEMENT	ADOBE READER FORMAT IN PDF ONLINE FROM HELP MENU
	EXTRACTMOJO WEB SITE	EXTRACTMOJO SUPPORT SITE AND FUTURE FORUM (REQUIRES THE LIVE NETWORK CONNECTION)
ABOUT	EXTRACTMOJO CREDITS	THREE BEAN TREE SOFTWARE DEVELOPERS AND BETA TESTERS
	EXTRACTMOJO NOTICES	TRADEMARK NOTICE
735	EXTRACTMOJO LICENSE KEY	KEY IS REQUIRED WHEN COMMUNICATING WITH GHC FOR ALL TECHNICAL SUPPORT

FIG. 8A

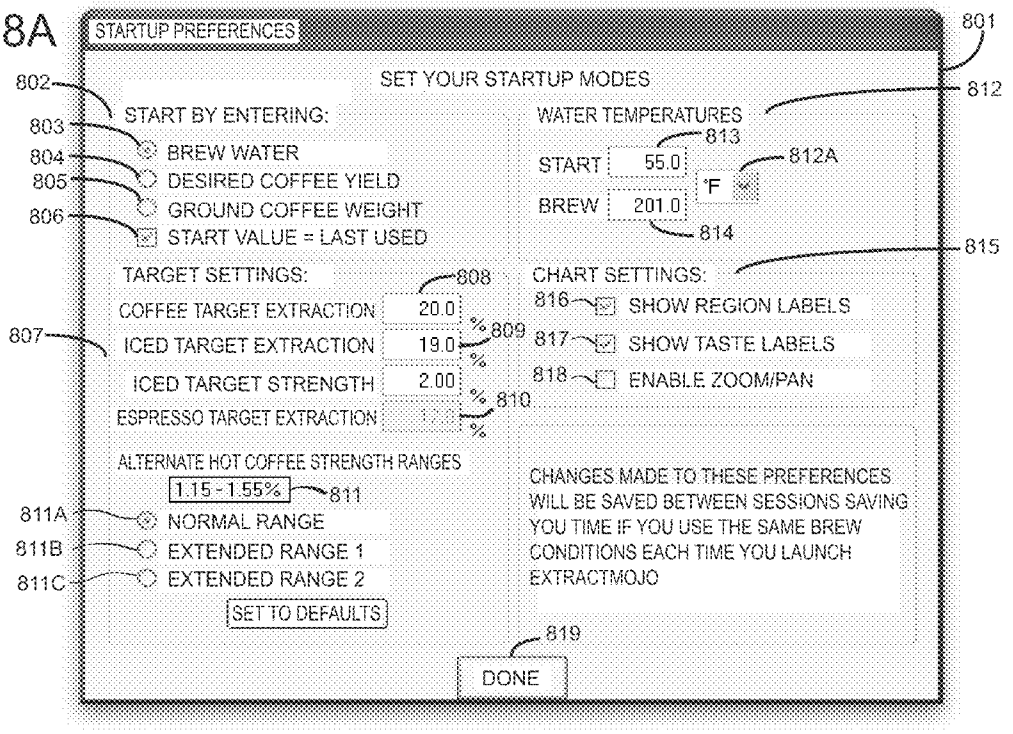

STARTUP PREFERENCES
801
SET YOUR STARTUP MODES
802
812
START BY ENTERING:
WATER TEMPERATURES
803
813
BREW WATER
START
55.0
804
812A
DESIRED COFFEE YIELD
°F
805
GROUND COFFEE WEIGHT
BREW
201.0
806
814
START VALUE = LAST USED
815
TARGET SETTINGS:
808
CHART SETTINGS:
COFFEE TARGET EXTRACTION
20.0
%
816
SHOW REGION LABELS
807
ICED TARGET EXTRACTION
19.0
%
809
817
SHOW TASTE LABELS
ICED TARGET STRENGTH
2.00
%
818
ENABLE ZOOM/PAN
ESPRESSO TARGET EXTRACTION
%
810
ALTERNATE HOT COFFEE STRENGTH RANGES
1.15 - 1.55%
811
CHANGES MADE TO THESE PREFERENCES WILL BE SAVED BETWEEN SESSIONS SAVING YOU TIME IF YOU USE THE SAME BREW CONDITIONS EACH TIME YOU LAUNCH EXTRACTMOJO
811A
NORMAL RANGE
811B
EXTENDED RANGE 1
811C
EXTENDED RANGE 2
SET TO DEFAULTS
819
DONE

FIG. 8B

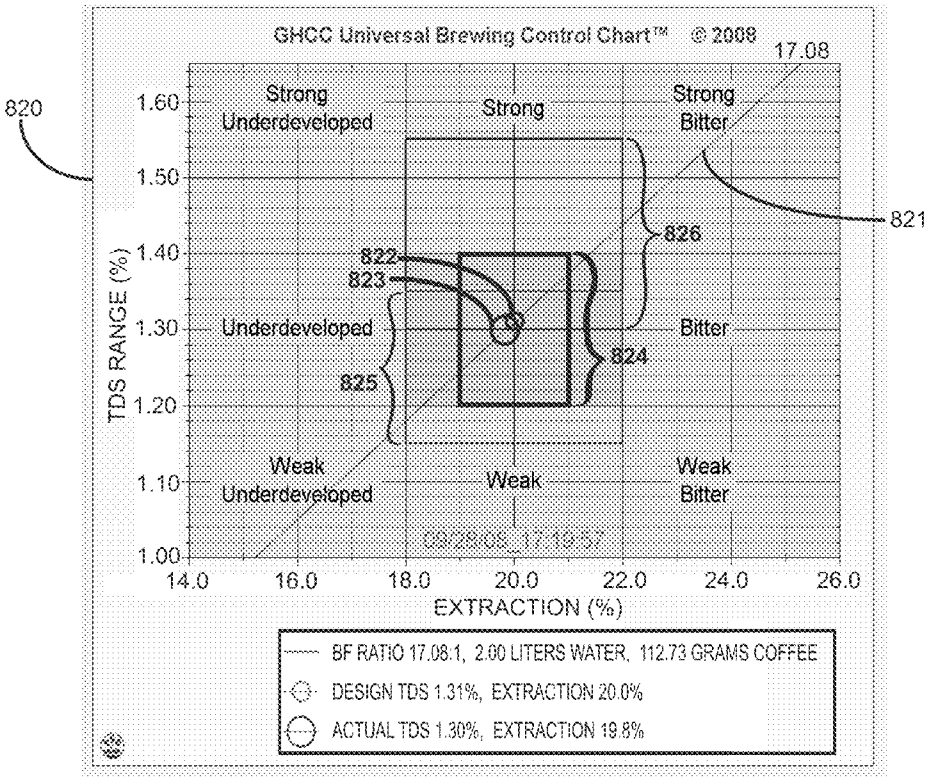

GHCC Universal Brewing Control Chart™ @ 2008
17.08
820
821
826
822
823
824
825
Strong Underdeveloped
Strong
Strong Bitter
Underdeveloped
Bitter
Weak Underdeveloped
Weak
Weak Bitter
TDS RANGE (%)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
14.0
16.0
18.0
20.0
22.0
24.0
26.0
EXTRACTION (%)
BF RATIO 17.08.1, 2.00 LITERS WATER, 112.73 GRAMS COFFEE
DESIGN TDS 1.31%, EXTRACTION 20.0%
ACTUAL TDS 1.30%, EXTRACTION 19.8%

FIG. 8C

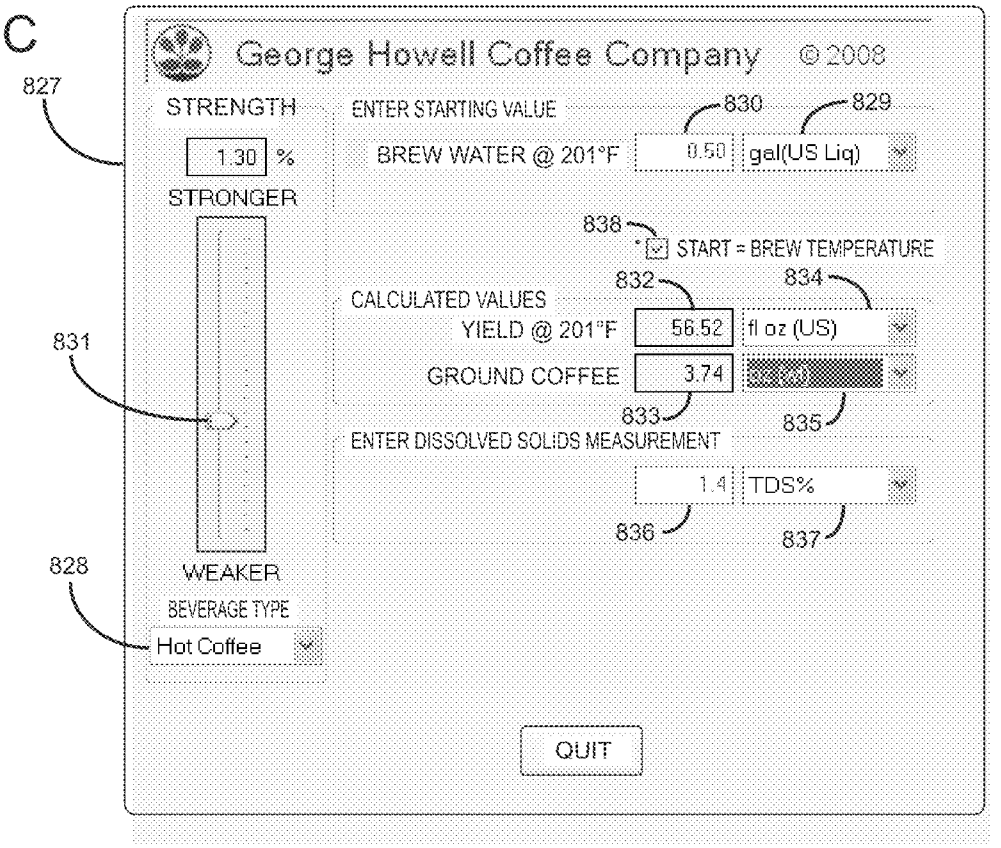

George Howell Coffee Company © 2008
827
STRENGTH
1.30 %
STRONGER
831
WEAKER
828
BEVERAGE TYPE
Hot Coffee
ENTER STARTING VALUE
830
829
BREW WATER @ 201°F
0.50
gal(US Liq)
838
START = BREW TEMPERATURE
832
834
CALCULATED VALUES
YIELD @ 201°F
56.52
fl oz (US)
GROUND COFFEE
3.74
833
835
ENTER DISSOLVED SOLIDS MEASUREMENT
1.4
TDS%
836
837
QUIT

FIG. 8D

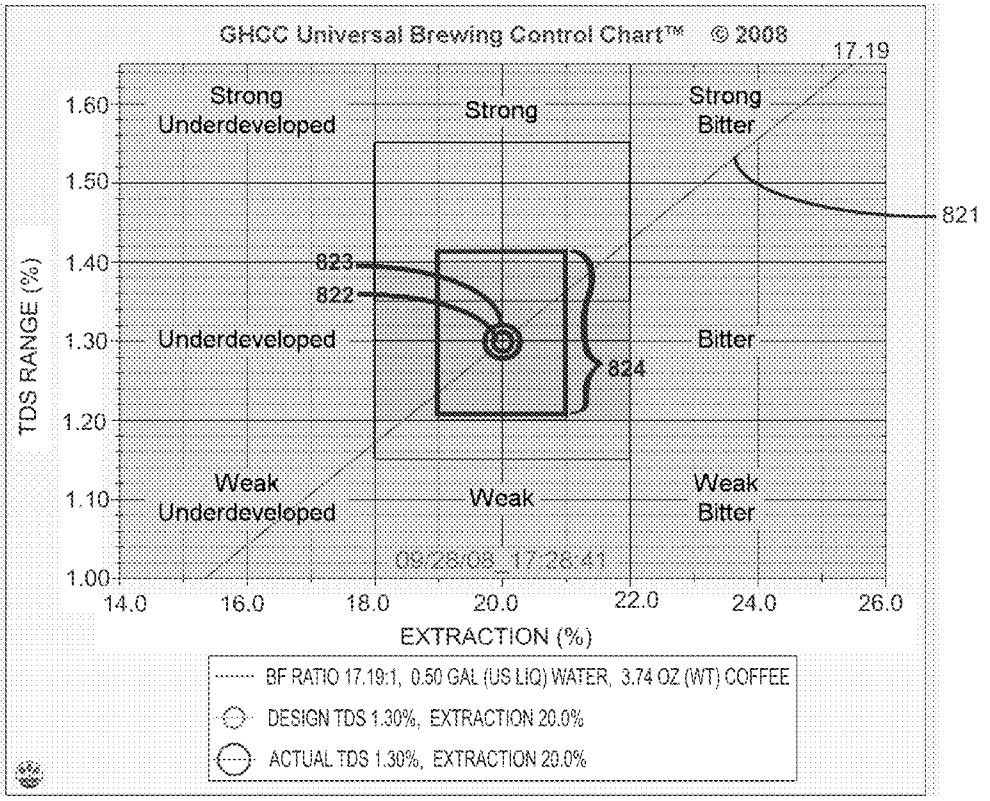

GHCC Universal Brewing Control Chart™ © 2008
17.19
Strong Underdeveloped
Strong
Strong Bitter
821
823
822
Underdeveloped
Bitter
824
Weak Underdeveloped
Weak
Weak Bitter
09/28/08 17:28:41
TDS RANGE (%)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
14.0
16.0
18.0
20.0
22.0
24.0
26.0
EXTRACTION (%)
BF RATIO 17.19:1, 0.50 GAL (US LIQ) WATER, 3.74 OZ (WT) COFFEE
DESIGN TDS 1.30%, EXTRACTION 20.0%
ACTUAL TDS 1.30%, EXTRACTION 20.0%

FIG. 8E

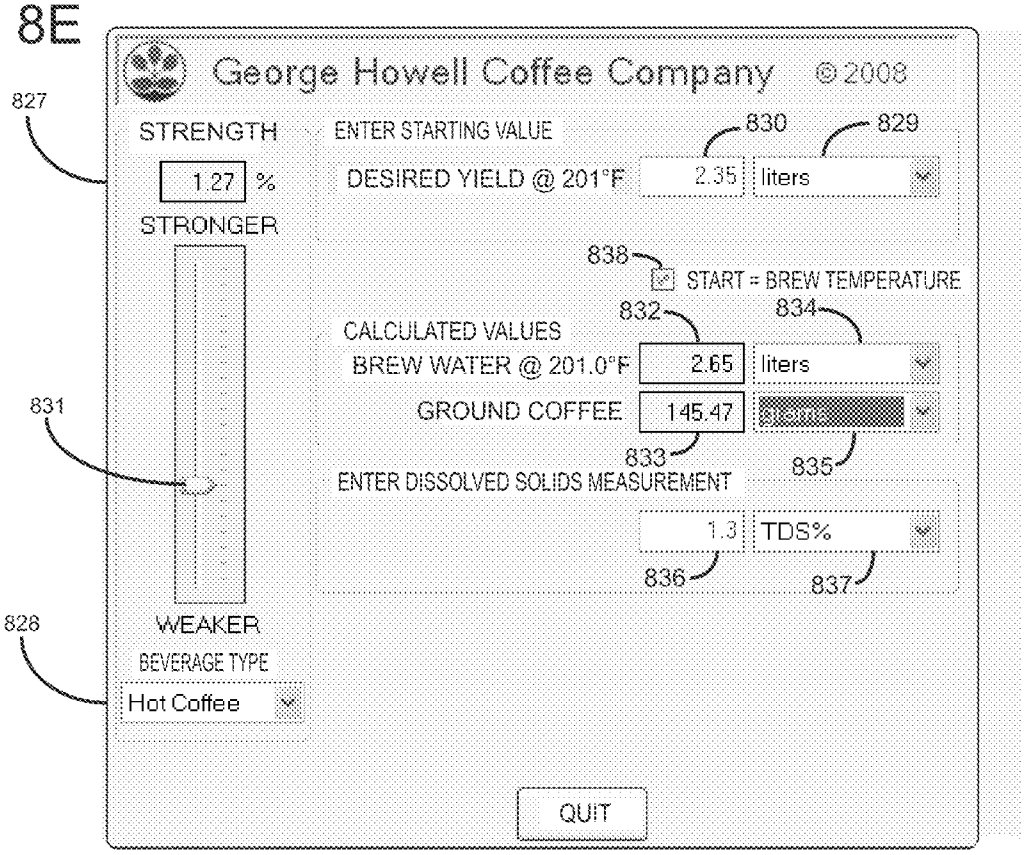

George Howell Coffee Company ©2008
827
STRENGTH
1.27 %
STRONGER
831
WEAKER
828
BEVERAGE TYPE
Hot Coffee
ENTER STARTING VALUE
830
829
DESIRED YIELD @ 201°F
2.35
liters
838
START = BREW TEMPERATURE
832
834
CALCULATED VALUES
BREW WATER @ 201.0°F
2.65
liters
GROUND COFFEE
145.47
833
835
ENTER DISSOLVED SOLIDS MEASUREMENT
1.3
TDS%
836
837
QUIT

FIG. 8F

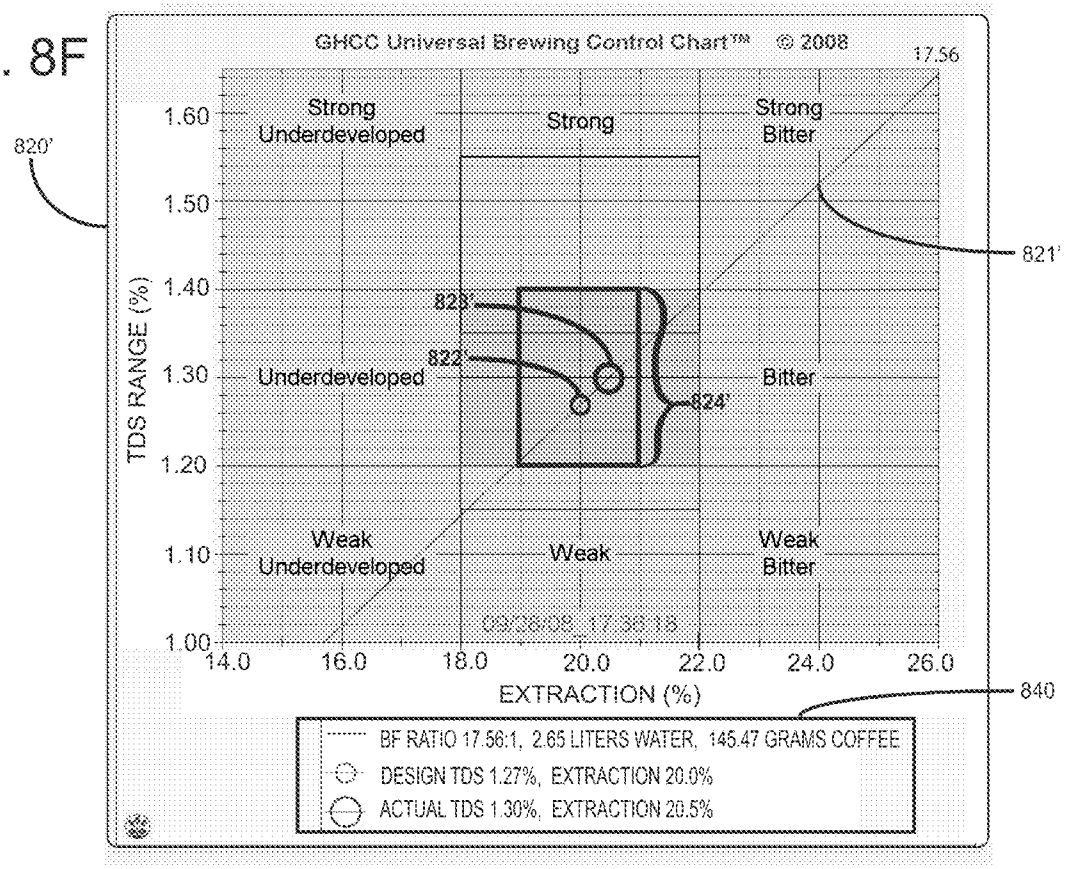

GHCC Universal Brewing Control Chart™ © 2008
17.56
820'
821'
Strong Underdeveloped
Strong
Strong Bitter
Underdeveloped
Bitter
Weak Underdeveloped
Weak
Weak Bitter
823
822
824'
TDS RANGE (%)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
14.0
16.0
18.0
20.0
22.0
24.0
26.0
EXTRACTION (%)
840
BF RATIO 17.56:1, 2.65 LITERS WATER, 145.47 GRAMS COFFEE
DESIGN TDS 1.27%, EXTRACTION 20.0%
ACTUAL TDS 1.30%, EXTRACTION 20.5%

FIG. 8G

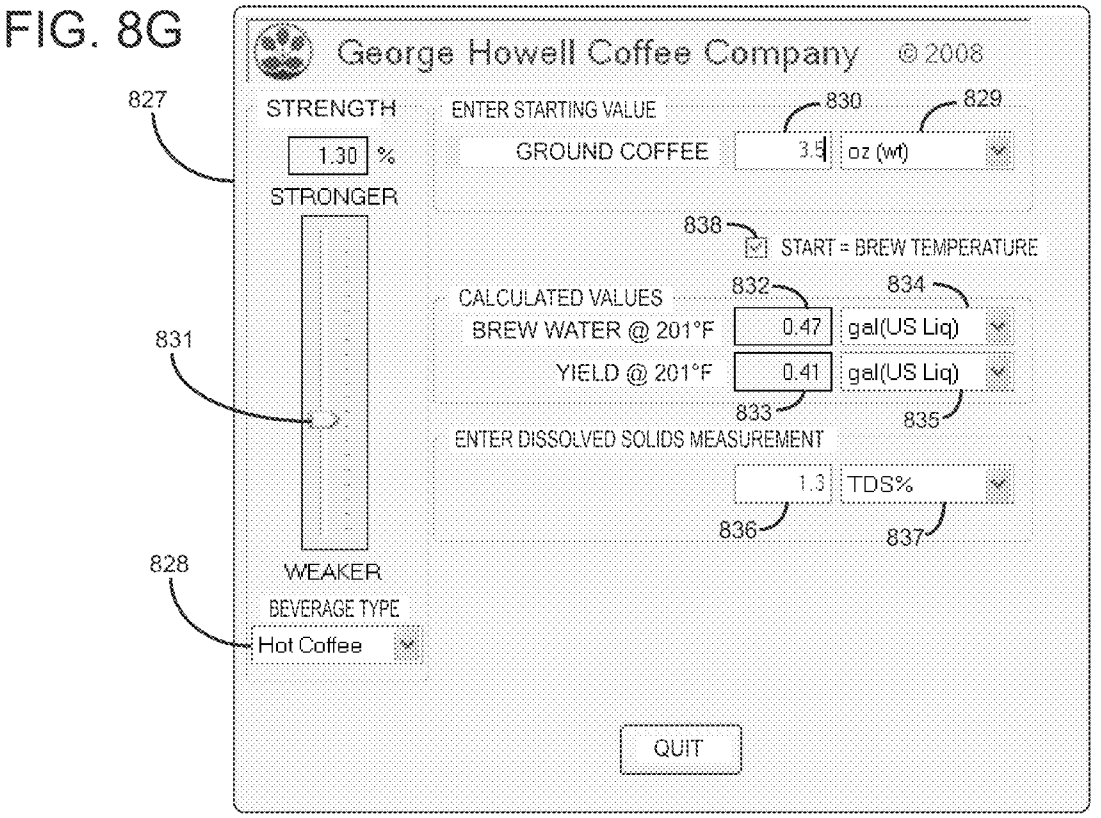

George Howell Coffee Company
© 2008
827
STRENGTH
1.30
%
STRONGER
831
WEAKER
828
BEVERAGE TYPE
Hot Coffee
ENTER STARTING VALUE
830
829
GROUND COFFEE
3.5
oz (wt)
838
START = BREW TEMPERATURE
CALCULATED VALUES
832
834
BREW WATER @ 201°F
0.47
gal(US Liq)
YIELD @ 201°F
0.41
gal(US Liq)
833
835
ENTER DISSOLVED SOLIDS MEASUREMENT
1.3
TDS%
836
837
QUIT

FIG. 8H

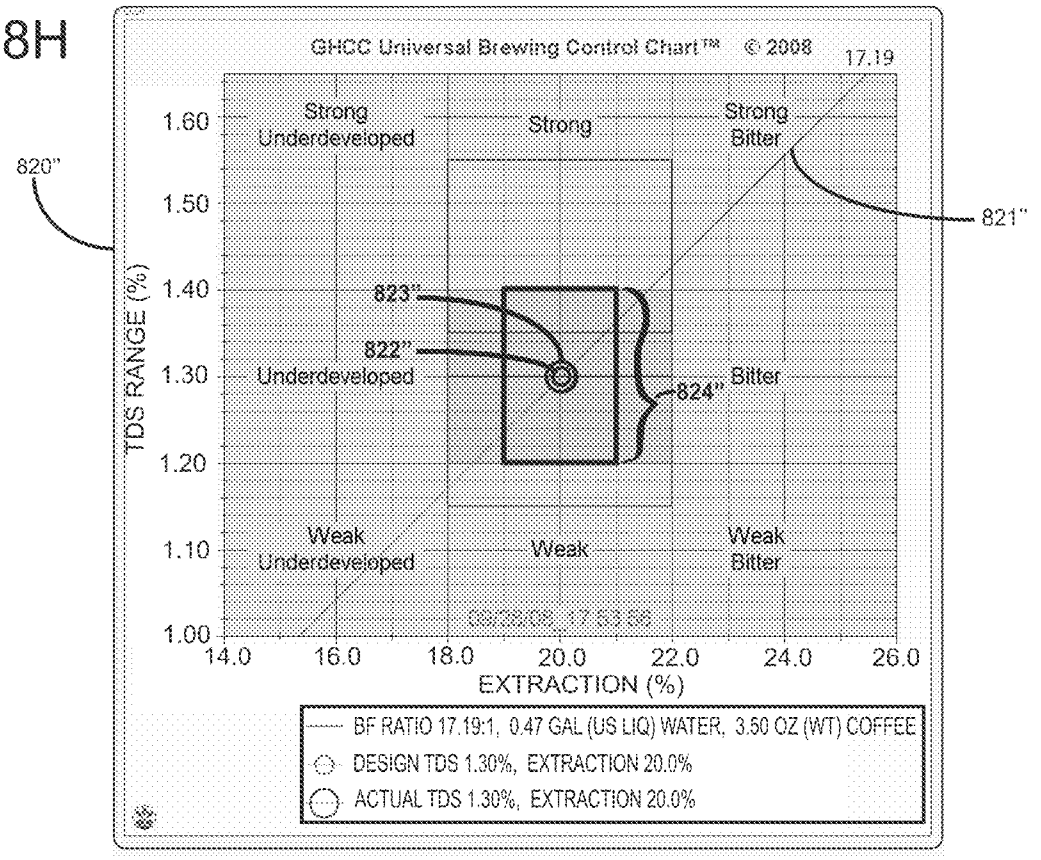

GHCC Universal Brewing Control Chart™ © 2008
17.19
820"
821"
823"
822"
824"
Strong Underdeveloped
Strong
Strong Bitter
Underdeveloped
Bitter
Weak Underdeveloped
Weak
Weak Bitter
TDS RANGE (%)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
14.0
16.0
18.0
20.0
22.0
24.0
26.0
EXTRACTION (%)
BF RATIO 17.19:1, 0.47 GAL (US LIQ) WATER, 3.50 OZ (WT) COFFEE
DESIGN TDS 1.30%, EXTRACTION 20.0%
ACTUAL TDS 1.30%, EXTRACTION 20.0%

FIG. 8I

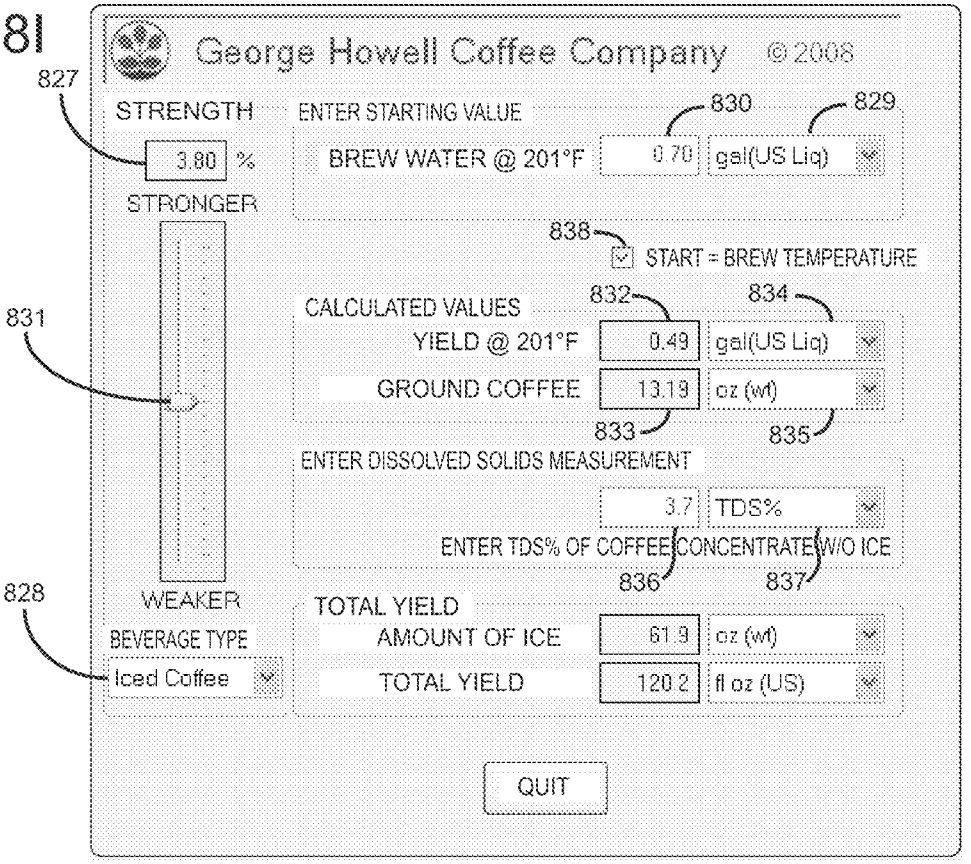

George Howell Coffee Company
©2008
827
STRENGTH
3.80
%
STRONGER
WEAKER
831
828
BEVERAGE TYPE
Iced Coffee
ENTER STARTING VALUE
830
829
BREW WATER @ 201°F
0.70
gal(US Liq)
838
START = BREW TEMPERATURE
CALCULATED VALUES
832
834
YIELD @ 201°F
0.49
gal(US Liq)
GROUND COFFEE
13.19
oz (wt)
833
835
ENTER DISSOLVED SOLIDS MEASUREMENT
3.7
TDS%
ENTER TDS% OF COFFEE CONCENTRATE W/O ICE
836
837
TOTAL YIELD
AMOUNT OF ICE
61.9
oz (wt)
TOTAL YIELD
120.2
fl oz (US)
QUIT

FIG. 8J

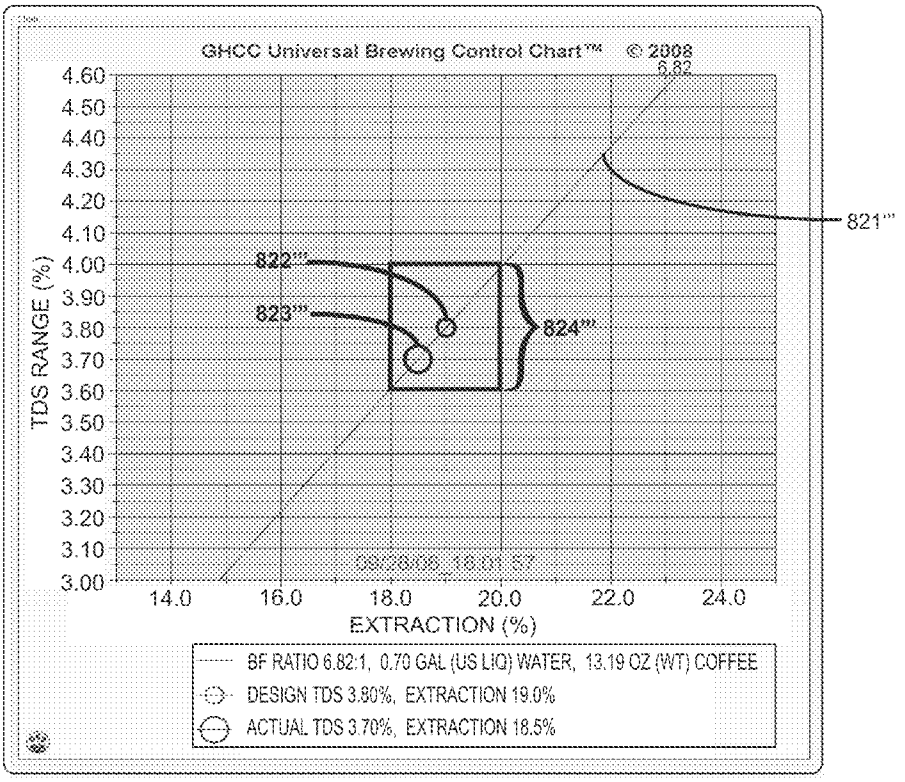

GHCC Universal Brewing Control Chart™ © 2008
6.82
821""
822""
823""
824""
TDS RANGE (%)
4.60
4.50
4.40
4.30
4.20
4.10
4.00
3.90
3.80
3.70
3.60
3.50
3.40
3.30
3.20
3.10
3.00
14.0
16.0
18.0
20.0
22.0
24.0
EXTRACTION (%)
BF RATIO 6.82:1, 0.70 GAL (US LIQ) WATER, 13.19 OZ (WT) COFFEE
DESIGN TDS 3.80%, EXTRACTION 19.0%
ACTUAL TDS 3.70%, EXTRACTION 18.5%

FIG. 9A

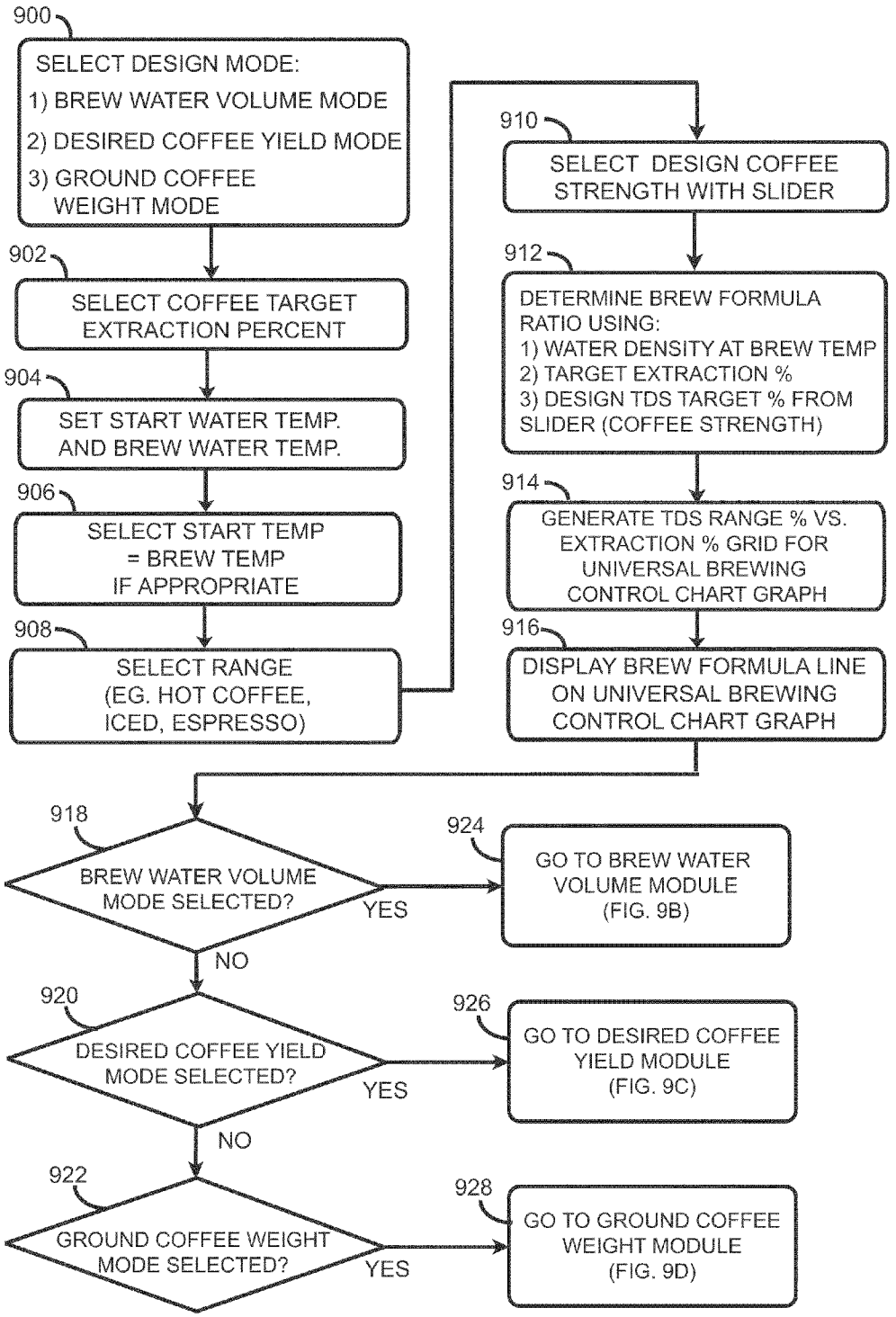

900
SELECT DESIGN MODE:
1) BREW WATER VOLUME MODE
2) DESIRED COFFEE YIELD MODE
3) GROUND COFFEE WEIGHT MODE
902
SELECT COFFEE TARGET EXTRACTION PERCENT
904
SET START WATER TEMP. AND BREW WATER TEMP.
906
SELECT START TEMP = BREW TEMP IF APPROPRIATE
908
SELECT RANGE (EG. HOT COFFEE, ICED, ESPRESSO)
910
SELECT DESIGN COFFEE STRENGTH WITH SLIDER
912
DETERMINE BREW FORMULA RATIO USING:
1) WATER DENSITY AT BREW TEMP
2) TARGET EXTRACTION %
3) DESIGN TDS TARGET % FROM SLIDER (COFFEE STRENGTH)
914
GENERATE TDS RANGE % VS. EXTRACTION % GRID FOR UNIVERSAL BREWING CONTROL CHART GRAPH
916
DISPLAY BREW FORMULA LINE ON UNIVERSAL BREWING CONTROL CHART GRAPH
918
BREW WATER VOLUME MODE SELECTED?
YES
NO
924
GO TO BREW WATER VOLUME MODULE (FIG. 9B)
920
DESIRED COFFEE YIELD MODE SELECTED?
YES
NO
926
GO TO DESIRED COFFEE YIELD MODULE (FIG. 9C)
922
GROUND COFFEE WEIGHT MODE SELECTED?
YES
928
GO TO GROUND COFFEE WEIGHT MODULE (FIG. 9D)

FIG. 9B

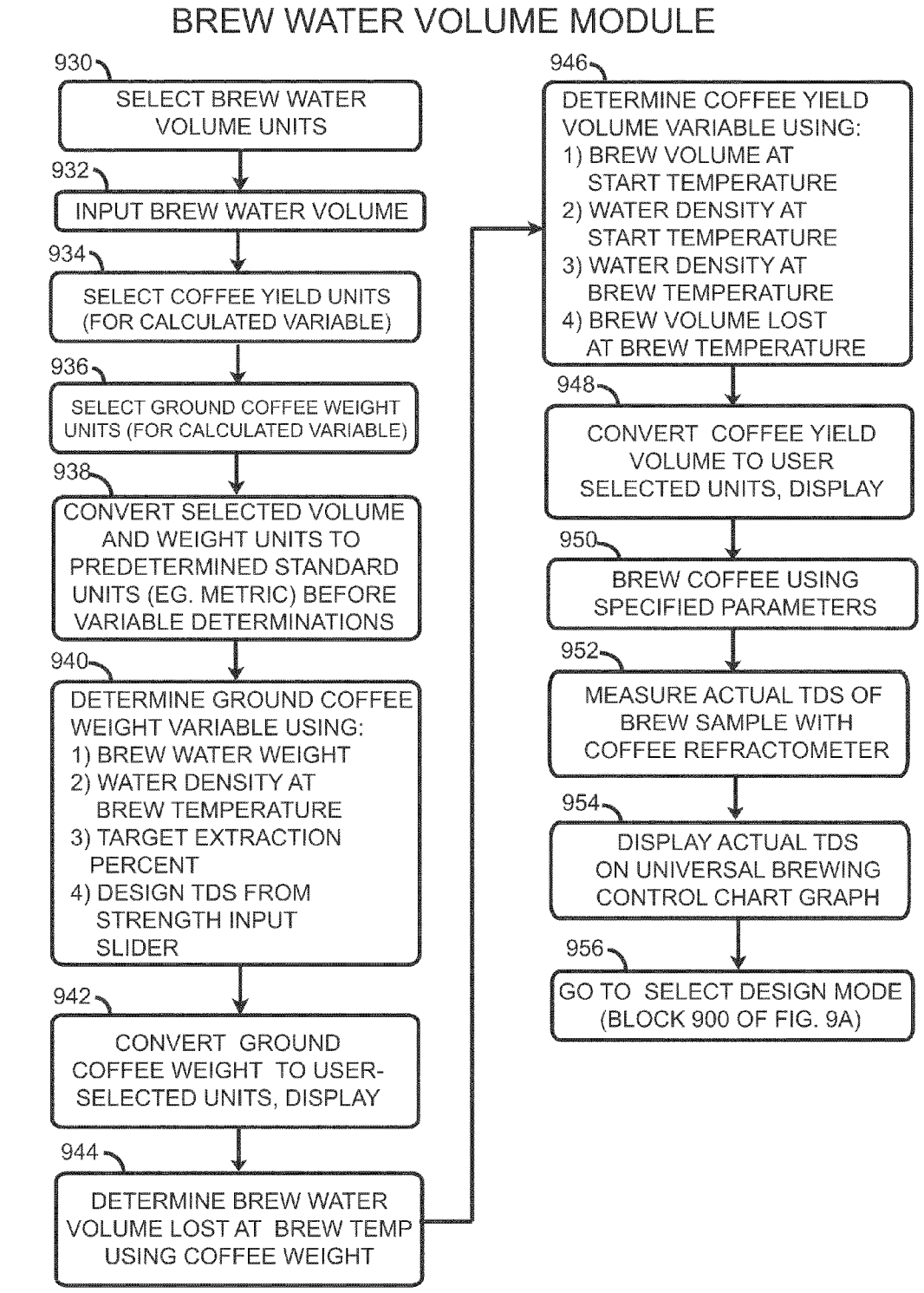

BREW WATER VOLUME MODULE
930
SELECT BREW WATER VOLUME UNITS
932
INPUT BREW WATER VOLUME
934
SELECT COFFEE YIELD UNITS (FOR CALCULATED VARIABLE)
936
SELECT GROUND COFFEE WEIGHT UNITS (FOR CALCULATED VARIABLE)
938
CONVERT SELECTED VOLUME AND WEIGHT UNITS TO PREDETERMINED STANDARD UNITS (EG. METRIC) BEFORE VARIABLE DETERMINATIONS
940
DETERMINE GROUND COFFEE WEIGHT VARIABLE USING:
1) BREW WATER WEIGHT
2) WATER DENSITY AT BREW TEMPERATURE
3) TARGET EXTRACTION PERCENT
4) DESIGN TDS FROM STRENGTH INPUT SLIDER
942
CONVERT GROUND COFFEE WEIGHT TO USER-SELECTED UNITS, DISPLAY
944
DETERMINE BREW WATER VOLUME LOST AT BREW TEMP USING COFFEE WEIGHT
946
DETERMINE COFFEE YIELD VOLUME VARIABLE USING:
1) BREW VOLUME AT START TEMPERATURE
2) WATER DENSITY AT START TEMPERATURE
3) WATER DENSITY AT BREW TEMPERATURE
4) BREW VOLUME LOST AT BREW TEMPERATURE
948
CONVERT COFFEE YIELD VOLUME TO USER SELECTED UNITS, DISPLAY
950
BREW COFFEE USING SPECIFIED PARAMETERS
952
MEASURE ACTUAL TDS OF BREW SAMPLE WITH COFFEE REFRACTOMETER
954
DISPLAY ACTUAL TDS ON UNIVERSAL BREWING CONTROL CHART GRAPH
956
GO TO SELECT DESIGN MODE (BLOCK 900 OF FIG. 9A)

FIG. 9C

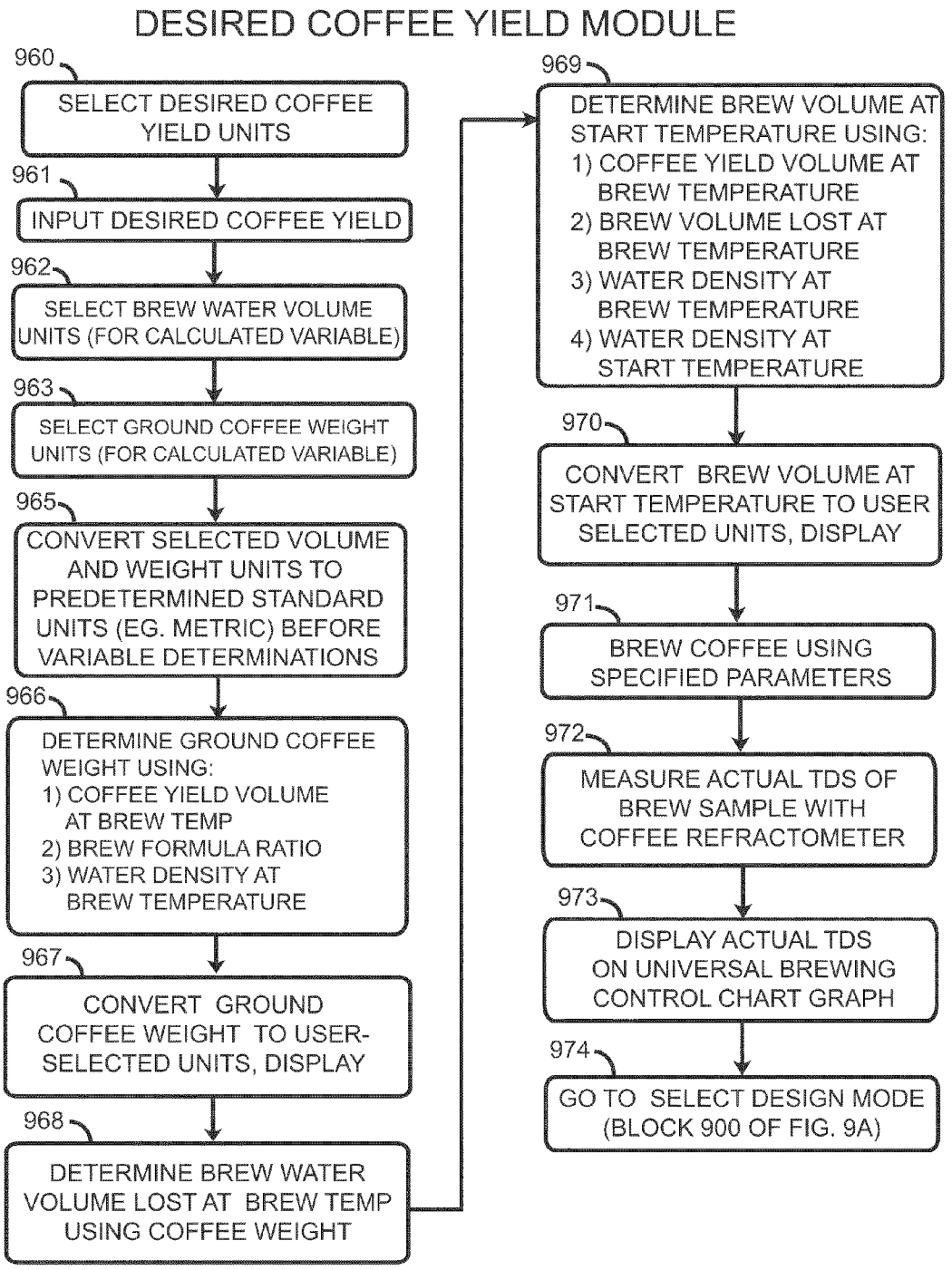

DESIRED COFFEE YIELD MODULE
960
SELECT DESIRED COFFEE YIELD UNITS
961
INPUT DESIRED COFFEE YIELD
962
SELECT BREW WATER VOLUME UNITS (FOR CALCULATED VARIABLE)
963
SELECT GROUND COFFEE WEIGHT UNITS (FOR CALCULATED VARIABLE)
965
CONVERT SELECTED VOLUME AND WEIGHT UNITS TO PREDETERMINED STANDARD UNITS (EG. METRIC) BEFORE VARIABLE DETERMINATIONS
966
DETERMINE GROUND COFFEE WEIGHT USING:
1) COFFEE YIELD VOLUME AT BREW TEMP
2) BREW FORMULA RATIO
3) WATER DENSITY AT BREW TEMPERATURE
967
CONVERT GROUND COFFEE WEIGHT TO USER-SELECTED UNITS, DISPLAY
968
DETERMINE BREW WATER VOLUME LOST AT BREW TEMP USING COFFEE WEIGHT
969
DETERMINE BREW VOLUME AT START TEMPERATURE USING:
1) COFFEE YIELD VOLUME AT BREW TEMPERATURE
2) BREW VOLUME LOST AT BREW TEMPERATURE
3) WATER DENSITY AT BREW TEMPERATURE
4) WATER DENSITY AT START TEMPERATURE
970
CONVERT BREW VOLUME AT START TEMPERATURE TO USER SELECTED UNITS, DISPLAY
971
BREW COFFEE USING SPECIFIED PARAMETERS
972
MEASURE ACTUAL TDS OF BREW SAMPLE WITH COFFEE REFRACTOMETER
973
DISPLAY ACTUAL TDS ON UNIVERSAL BREWING CONTROL CHART GRAPH
974
GO TO SELECT DESIGN MODE (BLOCK 900 OF FIG. 9A)

FIG. 9D

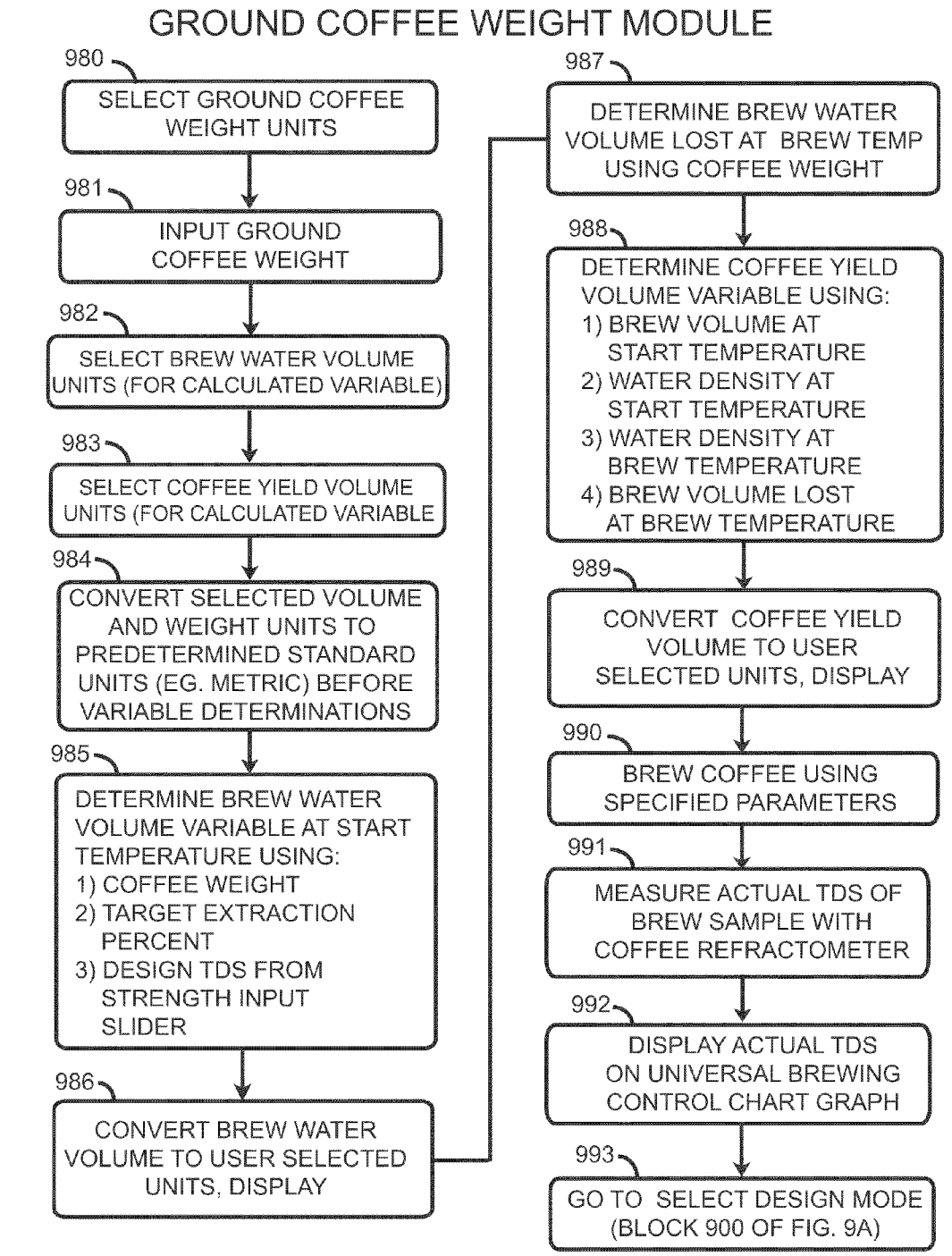

GROUND COFFEE WEIGHT MODULE
980
SELECT GROUND COFFEE WEIGHT UNITS
981
INPUT GROUND COFFEE WEIGHT
982
SELECT BREW WATER VOLUME UNITS (FOR CALCULATED VARIABLE)
983
SELECT COFFEE YIELD VOLUME UNITS (FOR CALCULATED VARIABLE
984
CONVERT SELECTED VOLUME AND WEIGHT UNITS TO PREDETERMINED STANDARD UNITS (EG. METRIC) BEFORE VARIABLE DETERMINATIONS
985
DETERMINE BREW WATER VOLUME VARIABLE AT START TEMPERATURE USING:
1) COFFEE WEIGHT
2) TARGET EXTRACTION PERCENT
3) DESIGN TDS FROM STRENGTH INPUT SLIDER
986
CONVERT BREW WATER VOLUME TO USER SELECTED UNITS, DISPLAY
987
DETERMINE BREW WATER VOLUME LOST AT BREW TEMP USING COFFEE WEIGHT
988
DETERMINE COFFEE YIELD VOLUME VARIABLE USING:
1) BREW VOLUME AT START TEMPERATURE
2) WATER DENSITY AT START TEMPERATURE
3) WATER DENSITY AT BREW TEMPERATURE
4) BREW VOLUME LOST AT BREW TEMPERATURE
989
CONVERT COFFEE YIELD VOLUME TO USER SELECTED UNITS, DISPLAY
990
BREW COFFEE USING SPECIFIED PARAMETERS
991
MEASURE ACTUAL TDS OF BREW SAMPLE WITH COFFEE REFRACTOMETER
992
DISPLAY ACTUAL TDS ON UNIVERSAL BREWING CONTROL CHART GRAPH
993
GO TO SELECT DESIGN MODE (BLOCK 900 OF FIG. 9A)

FIG. 10A

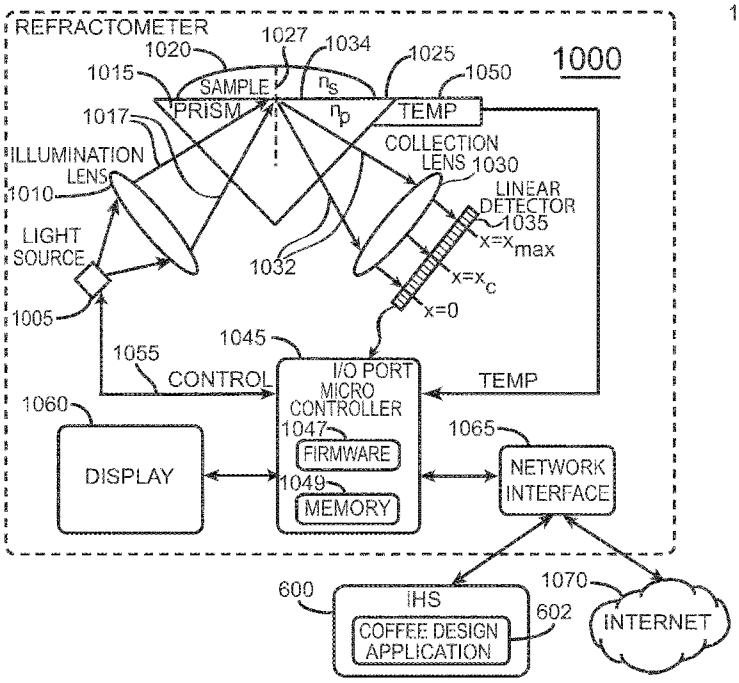


FIG. 10B

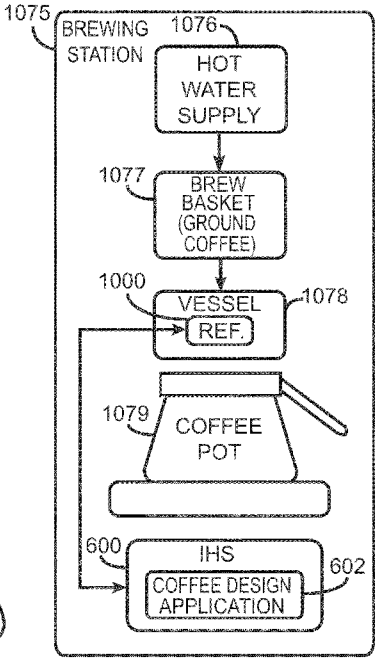


FIG. 11A

METHOD OF CALIBRATING AND CORRELATING A REFRACTOMETER TO TAKE A TDS READING

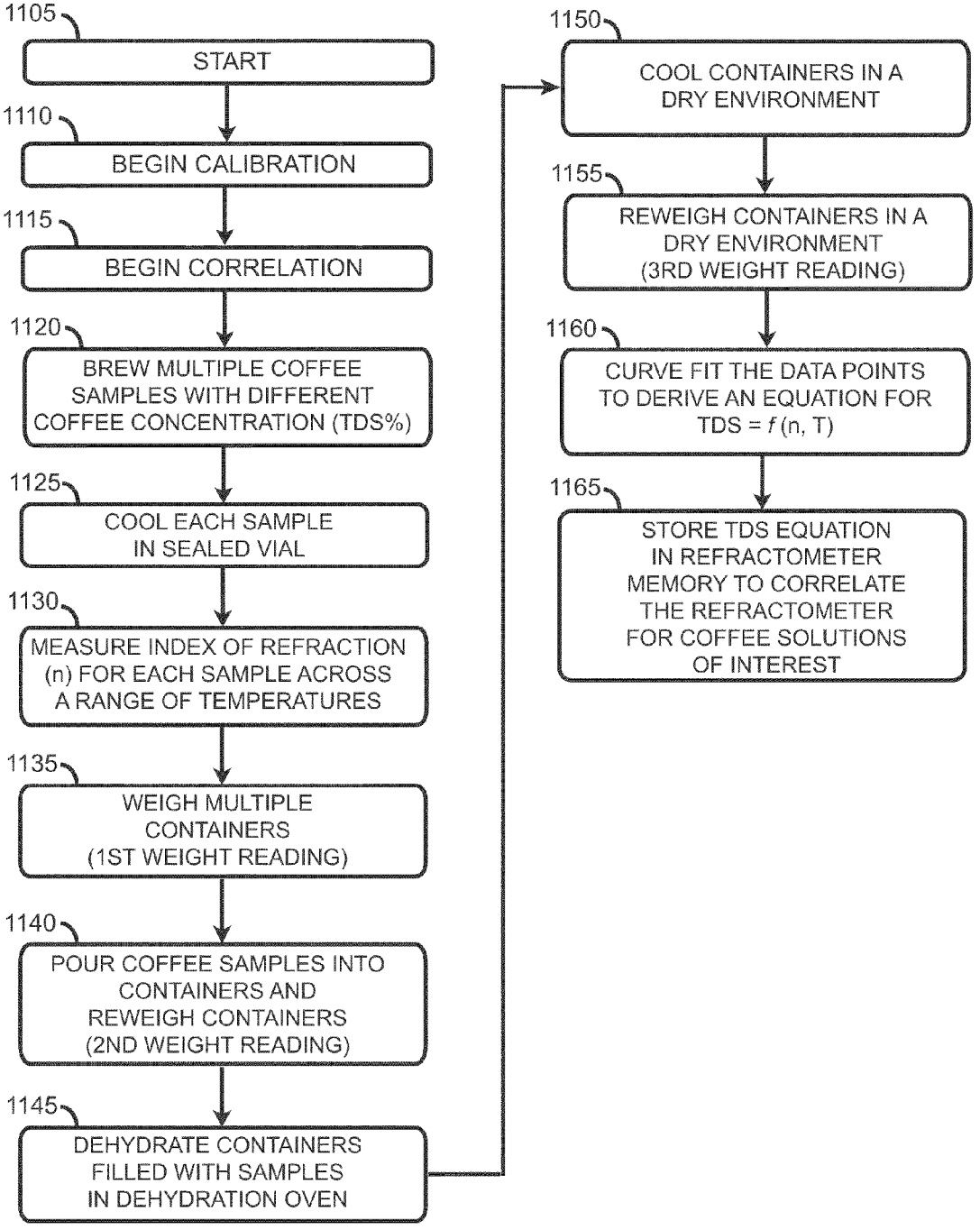
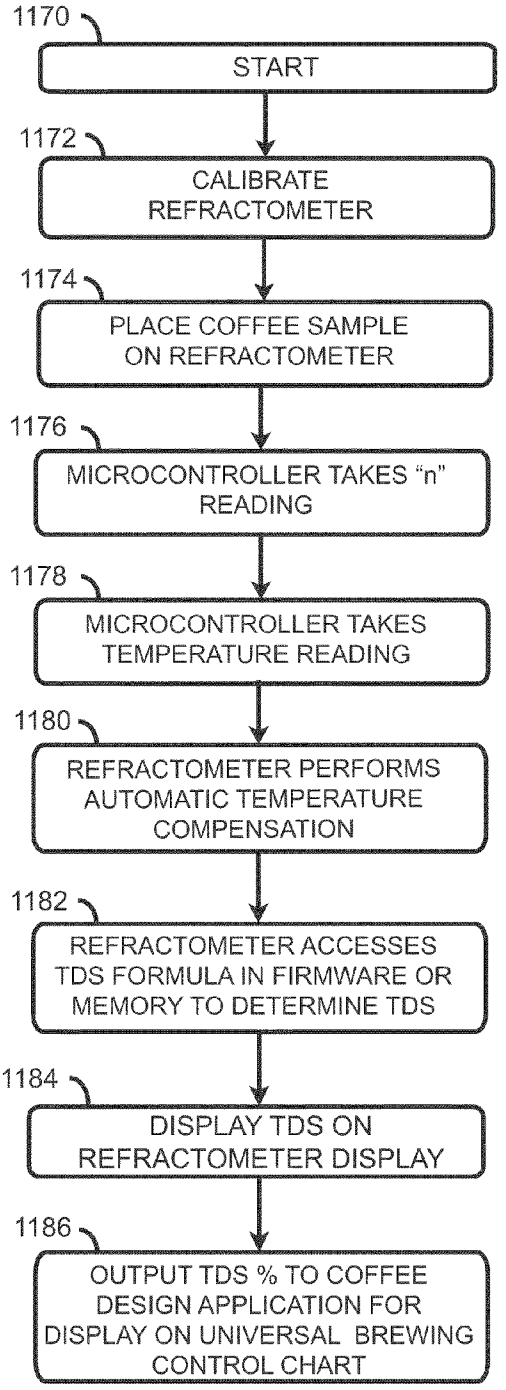


FIG. 11B

METHOD OF TAKING A TDS% READING OF A COFFEE BREW SAMPLE WITH THE REFRACTOMETER



COFFEE REFRACTOMETER METHOD AND APPARATUS

RELATED PATENT APPLICATIONS

This patent application relates to the U.S. patent application by Fedele, et al., entitled "METHOD AND APPARATUS FOR BREWING COFFEE VIA UNIVERSAL COFFEE BREWING CHART GENERATION", application Ser. No. 12/247,231, filed Oct. 8, 2008, which is assigned to the same assignee as the subject patent application and which is incorporated herein by reference in its entirety.

TECHNICAL FIELD OF THE INVENTION

The disclosures herein relate generally to the preparation of beverages for consumption, and more particularly, to brewing beverages such as coffee.

BACKGROUND

Quality standards in the specialty coffee industry established during the 1950's and 1960's that coffee extraction of approximately 20% (usually a range of ~18-22%) will achieve the best quality brewed coffee, using various brew methods. Over the ensuing years these established standards have been generally referred to as the gold-cup standard, and have been accepted internationally by many institutions, educational establishments, and standards committees. The precise extraction (solubles yield) and strength (solubles concentration) may be varied for particular coffees, to achieve finely tuned recipes for particular coffee cultivars, climates and growing regions, also known as terroir, and other characteristics.

Extraction (solubles yield) refers to the percentage of the dry coffee by weight that is removed by dissolving in water during the brewing process. Up to 30% of the available soluble solids in ground coffee can be extracted, with most of the remaining 70% being cellulose, and not soluble in water. However, generally speaking, extracting more than 22% will begin to sharply increase those components in coffee that contribute to the bitter taste defects associated with over-extraction. Extracting less than 18% is generally associated with weak, under-developed taste defects.

The finished brew is a balance between extraction (solubles yield) and strength (solubles concentration). Over-extracting results in the extraction of many of the bitter components of the remaining solids. These contribute significantly to those taste defects known as bitter, strong-bitter and weak bitter. Under-extracting causes a taste defect that is under-developed and can be weakly or strongly under-developed. As coffee dissolves, the bulk of the solids including the sweeter components dissolve during the first 30-50% of the brewing cycle, and the more bitter elements start to dissolve in the latter half of the brewing cycle. The highest quality coffee will have rich aroma, fullness of body, delicacy of flavor as well as clarity and unique character—all optimally balanced. Achieving these attributes requires a significant degree of precision during the coffee brewing process.

Strength (solubles concentration) refers to the measured amount of solids extracted into the final coffee solution. Strength may be expressed as the percentage total dissolved solids (% TDS). For example, for 100 grams of a coffee measuring 1.3% TDS, there are 98.7 grams of water, and 1.3 grams of dissolved coffee solids in solution.

Refractive index measurements have been used for process control in the food industry since the 1940s. Typical measurements are usually for sugars in fruits such as melons, for orange and other juices, for sugar content in grapes for the wine industry, and many other examples.

SUMMARY

Accordingly, in one embodiment a method of determining the total dissolved solids (TDS) in brewed coffee is disclosed. The method includes providing a brewed coffee sample to a coffee refractometer. The method also includes determining, by the coffee refractometer, the index of refraction (n_s) of the brewed coffee sample. The method further includes determining, by the coffee refractometer, the temperature of the brewed coffee sample to provide temperature compensation to the coffee refractometer. The method still further includes accessing, by a processor in the refractometer, a memory store in the refractometer, the memory store including a TDS formula that expresses the TDS of brewed coffee as a function of the index of refraction (n_s) of brewed coffee and the temperature of brewed coffee, to determine the resultant TDS of the brewed coffee sample.

In another embodiment, a coffee refractometer is disclosed. The coffee refractometer includes a prism for receiving a brewed coffee sample thereon to form a prism-sample interface. The coffee refractometer also includes a processor that controls a light source to provide incident light to the prism-sample interface, the prism-sample interface refracting light toward a photodetector that couples to the processor. The coffee refractometer further include a temperature sensor, situated adjacent the prism-sample interface and coupled to the processor, that provides temperature information to the processor. The coffee refractometer still further includes a memory store, accessible by the processor, that stores a TDS formula that expresses the TDS of brewed coffee as a function of the index of refraction (n_s) of brewed coffee and the temperature of brewed coffee, to determine the resultant TDS of the brewed coffee sample.

In one embodiment, the TDS formula expresses TDS as a linear function of index of refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample. In another embodiment, the TDS formula expresses TDS as a quadratic function of index of refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample.

BRIEF DESCRIPTION OF THE DRAWINGS

The appended drawings illustrate only exemplary embodiments of the invention and therefore do not limit its scope, because the inventive concepts lend themselves to other equally effective embodiments.

FIG. **1** shows a conventional soluble solids, extraction and brew formula graph.

FIG. **2** shows an expanded view of a conventional soluble solids, extraction and brew formula graph with specific regions of interest.

FIG. **3** shows a conventional soluble solids, extraction and brew formula chart with soluble solids represented in percent.

FIG. **4**A shows the conventional soluble solids, extraction and brew formula chart of FIG. **3** with both soluble solids and extraction represented in percent.

FIG. **4**B shows a conventional brewing chart for grams coffee per liter of water.

FIG. **4**C shows a conventional brewing chart for ounces coffee per 1.0 gallon water.

FIG. **4**D shows a conventional brewing chart for ounces coffee per half gallon water.

FIG. **4**E shows a conventional brewing chart for ounces coffee per 1.0 quart water.

FIG. **5** shows one embodiment of the disclosed universal coffee brewing chart with a particular representative brew formula line that extends through a region of interest that includes both a target coffee design point and an actual coffee design point.

FIG. **6**A shows an information handling system (IHS) including the disclosed coffee design application embodied in a computer program product.

FIG. **6**B shows a small form factor handheld information handling system (IHS) including the disclosed coffee design application embedded or stored therein.

FIGS. **7**A-**7**B show a representative coffee design and measurement process flow.

FIG. **8**A shows a startup preferences window of the disclosed coffee design application wherein a brew water volume mode is selected.

FIG. **8**B shows a universal brewing control chart resulting from the disclosed coffee design application operating in the brew water volume mode.

FIG. **8**C shows a main window of the disclosed coffee design application operating in the brew water volume mode wherein the user specifies an amount of brew water volume as input.

FIG. **8**D shows another universal brewing control chart resulting from the disclosed coffee design application operating in the brew water volume mode.

FIG. **8**E shows the main window of the disclosed coffee design application operating in the desired coffee yield mode wherein the user specifies an amount of desired coffee yield as input.

FIG. **8**F shows a universal brewing control chart resulting from the disclosed coffee design application operating in the desired coffee yield mode.

FIG. **8**G shows the main window of the disclosed coffee design application operating in the ground coffee weight mode wherein the user specifies an amount of ground coffee weight as input.

FIG. **8**H shows a universal brewing control chart resulting from the disclosed coffee design application operating in the ground coffee weight mode.

FIG. **8**I shows the main window of the disclosed coffee design application for a iced coffee beverage wherein the disclosed coffee design application operates in the brew water volume mode wherein the user specifies an amount of brew water volume as input.

FIG. **8**J shows a universal brewing control chart resulting from the disclosed coffee design application operating in the brew water volume mode for an iced coffee beverage.

FIG. **9**A is a flowchart showing process flow in the disclosed coffee design methodology.

FIG. **9**B is a flowchart that depicts process flow in a brew water volume mode of the disclosed methodology.

FIG. **9**C is a flowchart that depicts process flow in a desired coffee yield mode of the disclosed methodology.

FIG. **9**D is a flowchart that depicts process flow in a ground coffee weight mode of the disclosed methodology.

FIG. **10**A is a block diagram of the disclosed coffee refractometer.

FIG. **10**B is a block diagram of a brewing station that employs the disclosed coffee design system and the disclosed coffee refractometer.

FIG. **11**A is a flowchart that depicts process steps in calibrating and correlating the disclosed refractometer to read total dissolved solids (TDS).

FIG. **11**B is a flowchart that depicts process steps in operating the disclosed coffee refractometer to read the TDS of a coffee brew sample.

DETAILED DESCRIPTION

FIG. **1** is a prior original brewing chart that shows soluble solids vs. brew formula as a function of extraction percent, namely 5-40 percent as seen in the upper left of the chart (CBC Publication No. 27, 1969, p12.). The y axis represents soluble solids concentration (strength) in percent while the x axis represents the brew formula in gallons of water per pound of coffee. Hyperbolic curves representing soluble solids yield extraction in percent from 5-40% are illustrated. Of particular interest in this series of hyperbolas are region of interest **105** and the smaller region of interest **110**. Region of interest **105** relates to a study carried out by the Brewing Committee of the National Coffee Association, which judged brews prepared within this region for objective acceptability. The Midwest Research Institute carried out a more recent independent study from which it was concluded that the most acceptable coffee would result from preparation within the more refined region of interest **110**, for soluble solids concentration (strength) from 1.15 to 1.35 percent and soluble solids yield extraction between 18 and 22 percent (Niven, W. W., Jr. and Shaw, B. C., Critical Conditions for Quality Coffee Brewing, Coffee and Tea Industries 80, No. 4, 44, April. 1957. Tea and Coffee Trade Journal, 112, No. 4, 28-April. 1957. Coffee Brewing Center, Nos. 19 and 27, 1969. The brewing chart of FIG. **1** signifies that a very small area of the curves thereof (i.e. region of interest **105** or region of interest **110**) should be targeted for proper coffee extraction relative to the wide range of extraction possible. FIG. **2** is an enlargement of a portion of the brewing chart of FIG. **1** focusing on regions of interest **105** and **110**.

FIG. **3** is a conventional representation of the data for FIG. **1** and FIG. **2** including solubles concentration (strength) vs. solubles yield (extraction) with brew formula as the parameter. More particularly, the y axis of FIG. **3** represents extracted solids in solution (percent TDS or total dissolved solids) while the x axis represents extraction in ounces per pound (solubles yield). The plotted curves are nearly straight lines (curves) that correspond to the brew formula in gallons of water per pound of coffee. The plot of FIG. **3** identifies a substantially centered rectangular region of interest **305** as representing the ideal coffee brew. This region of interest **305** is the same as originally published by the CBC and as identified as developed by the Midwest Research Institute, region **110**, previously in FIGS. **1** and **2**. These plots assume the specific gravity of water at ambient temperature which may in fact be substantially different from the specific gravity of water at the actual brewing temperature. This assumption may have a negative impact on the brewing process and may affect the ability to reach a particular target percent of TDS of coffee in solution and a particular percent extraction if the ratio of coffee to water is determined at an incorrect temperature. Since the density of water changes as a function of temperature, the volume of water to weight of coffee ratios are affected accordingly. To further illustrate this problem, commercial brewer-extractors are typically preset to approximately 200 degrees F. and volume is calibrated at the boiler set point, whereas a home brewer typically uses water at tap or room temperature, i.e. an ambient temperature of approximately 50-65 degrees F. The volume of a given weight of water at room temperature will be significantly less than the volume of the same weight of water at 200 degrees F., because water is more dense at ambient than at 200 degrees. This

scenario can lead to inaccurate brewing results when using the coffee brewing chart of FIG. **3**.

FIG. **4**A is substantially the same coffee control brewing chart of FIG. **3** except that the x axis is now expressed in percent extraction, a more convenient unitless method of expression, instead of ounces extracted per pound of coffee. For example, if 3.2 ounces of coffee are extracted from 16 ounces of coffee, this corresponds to 20% extraction by weight. While the parameters of the x axis and y axis are expressed in percent, the brew formula of FIG. **4**A remains in units of gallons of water per pound of coffee, as was the case in the brewing chart of FIG. **3**. FIGS. **4**B-**4**E show a similar conventional representation of the typical brewing chart in common use today. For each brew batch size and unit of measure, separate conventional representations are needed, where such representations show separate brew formulas each labelled for the weight of ground coffee called for in that dedicated batch size. FIGS. **4**B-**4**E show separate charts required for each separate batch size, and units of measure used, including gallons of brew water per ounce of ground coffee, similarly half-gallons per ounce, liters per gram and quarts per ounce. Expressed alternatively, FIG. **4**B is a conventional brewing chart for grams coffee per liter water. FIG. **4**C is a conventional brewing chart for ounces coffee per 1.0 gallon water. FIG. **4**D is a conventional brewing chart for ounces coffee per half gallon water. FIG. **4**E is a conventional brewing chart for ounces coffee per 1.0 quart water.

FIG. **5** shows the universal coffee brewing chart that the disclosed coffee design software application may generate. Rectangle **505** denotes a region of interest of acceptable strength in percent total dissolved solids (% TDS or solubles concentration) and extraction percent (solubles yield) that are found to be very desirable for the experienced palate, typically from approx. 1.2% to approx. 1.4% strength and approx. 19% to approx. 21% extraction, more typically from approx. 1.15% to approx. 1.55% strength and approx. 18% to approx. 22% extraction. Such regions of interest may be defined specifically as being best suited for particular coffee cultivars, regions, roast styles, and terroir, and may be developed specifically as preferences or suggested recipes for brewing particular coffees, and may be further developed as a result of consumer taste profiles and overlaid as new regions of interest to suit a particular consumer preference, roaster preference or user preference. For example, consumer preferences may be plotted on an additional z-scale, and consider an n-point scale (from "like intensely" to "dislike intensely") which is plotted as a three-dimensional surface chart, where the y-scale is solubles concentration (%) and the X-scale is solubles yield (%). The surface chart may then be resolved to a colorized two-dimensional chart by viewing the three-dimensional chart from the top, and plotting the z-axis (consumer preference) in colors and in two dimensions, along with the traditional solubles yield (percent extraction) and solubles concentration (percent TDS, strength) superimposed on the same two-dimensional chart. Such a representation may provide an update to the most recent "optimum balance" regions of interest, and as corrected for brew water temperature.

Brew formula line **510** represents the brew formula of water and coffee and makes the brew formula a dimensionless unit of measure by stating brew formula as a ratio (e.g. 17.19) of water to coffee by weight. This ratio remains constant despite variations in size of coffee batches brewed or the units used, thereby eliminating a requisite of separate brewing control charts for each different unit of measure or changes in batch size, as required in the past with conventional brewing control charts. Unfortunately, the conventional brewing control charts of FIGS. **1**-**3**, **4**A-**4**E are not flexible because a different brewing control chart is needed each time brewing batch size or units of measure changes. Moreover in these conventional charts, mixed units of volume of water are used with weight measurement units of coffee, mandating a new chart whenever a unit of measure or batch size changed. However, in one embodiment, the disclosed coffee design application and system is capable of generating a universal coffee brewing control chart that is stepless in portion sizes and continuous as coffee batch size, brew formulas, extraction and strength changes and as other variables change. The universal coffee brewing control chart also manages variable and mixed units, for example, brew water may be specified in gallons and coffee weight in grams, or water in liters and coffee weight in ounces. The disclosed coffee design application converts water volume at the temperature specified to weight to plot the correct brew formula ratio. Previous original brewing charts assumed water at room temperature, and conventional charts assumed water at 140 degrees F. as corrected for the hydrometer instrument used. However, the disclosed coffee design application corrects for the actual brew water temperature. The disclosed coffee design application will replot the control chart steplessly and in real time as the user changes design inputs. For example, as brew strength increases, brew formula line **505** may be continuously replotted to the left and higher in FIG. **5**. Likewise, as brew strength decreases, brew formula line **505** may shift continuously to the right and lower in FIG. **5**. With each change in the brew formula line, all other design output parameters are calculated and displayed continuously and in real time, and portions are determined based on actual start and brew water temperatures to maintain portions true to the brew formula ratio, eliminating previous errors in the range of 2-4%. With the universal coffee brew control chart that this application provides, there is no need for a series of different brew control charts for each batch size or units of measure.

The following EQUATION 1 determines Percent Extraction using the Brew Formula Ratio, Water Density at Brew Temp and Percent TDS as variables. More particularly, from TDS %=0 to TDS %=10, the disclosed coffee design application determines Extraction for each TDS point using EQUATION 1:

$$\text{EXTRACTION \%} = (BF\ \text{Ratio} - \text{water density_(g/ml @ brew Temp)} * \text{waterLost_ml/g_coffee}) / (1/TDS\% - 0.01)) \quad \text{Equation 1}$$

To calculate Extraction % using this equation, Brew Formula Ratio (BF Ratio) should first be determined from the user input using the Strength Slider (TDS %) setting and the Target Extraction %. If the user changes the Strength Slider, then the BF Ratio changes and the brew formula line moves to a new location on the brew chart. Water density at brew temperature and water lost per gram are constants. Equation 1 is not a linear equation. The disclosed coffee design application plots the resulting point pairs on the control chart of FIG. **5** to draw the brew formula line **510**.

The brew formula line **510** is drawn from generated data point pairs by incrementing Percent TDS from 0 to 10 and calculating Percent Extraction. The universal coffee brewing chart of FIG. **5** plots Percent TDS vs. Percent Extraction. The slope of the brew formula line **510** is delta TDS over delta Extraction, namely change in TDS over change in extraction. The Brew Formula is used to calculate these point pairs. As will be explained in more detail below, the disclosed coffee design application will plot the intended coffee design as a small circle **515** (red plot point) for strength (solubles concentration) and extraction (solubles yield) on the brew formula line **510**. Subsequently, after brewing a sample batch of

coffee according to the specified design parameters and measuring the total dissolved (TDS %) with the disclosed coffee refractometer, the disclosed coffee application will plot the actual measured coffee design as a large circle **520** (blue plot point) for strength (solubles concentration) and extraction (solubles yield) on the brew formula line **510**.

FIG. **6**A shows an information handling system **600** on which the coffee design application may execute as a computer program product. More particularly, FIG. **6** shows an information handling system (IHS) **600** that includes coffee design application **602** and an operating system **606**. IHS **600** may initially store coffee design application **602** as a computer program product on a medium **608**, such as a CD, DVD or other medium. In this particular embodiment, IHS **600** includes a processor **610** having multiple compute elements (CEs) on a common semiconductor die **612**. IHS **600** processes, transfers, communicates, modifies, stores or otherwise handles information in digital form, analog form or other form. IHS **600** includes a bus **615** that couples processor **610** to system memory **620** via a memory controller **625** and memory bus **630**. A video graphics controller **635** couples display **640** to bus **615**. Nonvolatile storage **645**, such as a hard disk drive, CD drive, DVD drive, or other nonvolatile storage couples to bus **615** to provide IHS **600** with permanent storage of information. Operating system **606** loads in memory **620** to govern the operation of IHS **600**. I/O devices **650**, such as a keyboard and a mouse pointing device, couple to bus **615** via I/O controller **655** and I/O bus **660**. One or more expansion busses **665**, such as USB, IEEE 1394 bus, ATA, SATA, PCI, PCIE and other busses, couple to bus **615** to facilitate the connection of peripherals and devices to IHS **600**. A network interface adapter **670** couples to bus **615** to enable IHS **600** to connect by wire or wirelessly to a network and other information handling systems. While FIG. **6**A shows one IHS that employs processor **610**, the IHS may take many forms. For example, IHS **600** may take the form of a desktop, server, portable, laptop, notebook, or other form factor computer or data processing system. IHS **600** may take other form factors such as a gaming device, a personal digital assistant (PDA), a handheld computing device, a portable telephone device, a communication device or other devices that include a processor and memory.

A user of IHS **600** loads medium **608** into IHS **600** to store coffee design application **602** on non-volatile storage **645** as coffee design application **602'**. When IHS **600** initializes, the IHS loads operating system **606** into system memory **620** for execution as operating system **606'**. The IHS also loads coffee design application **602'** into system memory **620** for execution as coffee design application **602"**.

FIG. **6**B shows a hand-held information handling system **675** that exhibits a small form factor such as a personal digital assistant (PDA). For example, IHS **675** may be a portable telephone type device or hand-held computer, such as an IHS that executes Microsoft Windows CE, or a Palm Pilot type device or an iPhone type IHS or smart phone. (PalmPilot is a trademark of Palm, Inc. iPhone is a trademark of Apple Inc.) In this embodiment, coffee design application **602** is embedded within the small form factor IHS as shown in FIG. **6**B. In more detail, hand-held IHS **675** includes a microcontroller **676** that includes an internal memory **677** and firmware **678**. IHS **675** includes a non-volatile memory **679** coupled to microcontroller **676**. In one embodiment, non-volatile memory **679** stores coffee design application **602** therein as shown. In another embodiment, firmware **678** may contain coffee design application **602** or memory **677** may contain coffee design application **602**.

IHS **675** includes a sensor package **680** that includes an accelerometer sensor **681**, a proximity sensor **682**, a touch sensor **683** and a photo sensor **684**. Sensor package **680** couples to microcontroller **676**. IHS **675** further includes an RF communication package **685** that includes a 3G/GPRS/GSM phone communication module **686**, and EDGE phone communication module **687**, an IEEE 802.11 network communication module **688** and a Bluetooth local communication module **689**. RF communication package **686** couples to microcontroller **676**. Both a touch sensitive display **690** and a camera **691** couple to microcontroller **676** as shown. A global positioning system (GPS) module **692** also couples to microcontroller **676** to provide position information thereto.

In one embodiment, sensor package **680** generates a first position signal when IHS **675** exhibits a first spatial position or orientation such as a horizontal position, for example, with respect to a particular reference point. Sensor package **680** generates a second position signal when IHS **675** exhibits a second spatial position or orientation such as a vertical position with respect to the particular reference point. IHS **675** is configured to send the first and second position signals to coffee design application **602**. IHS **675** is further configured such that coffee design application receives user input from touch screen display **690** when sensor package **680** generates the first position signal indicating that the IHS **675** is in the first position. Coffee design application **602** responds to the first position signal and accepts user input when it receives the first position signal. For example, such user input may include user input preferences to set modes and temperatures, and user input commands to accept % TDS strength and other input variables using a combination of touch screen commands, buttons and text or number entry modes.

When coffee design application **602** receives the second position signal, indicating that the user has changed the orientation of the IHS **675** to the second position, coffee design application **602** senses this signal change and in response computes and plots the solution and charts results of the user inputs, including but not limited to the brew formula curve, required portions of coffee and water, and draws a universal brewing control chart on display **690**. In other words, the user holds IHS **676** horizontally while inputting information and flips the IHS **675** to a vertical position to command that IHS **675** draw a universal brewing control chart on the display **690**. It is noted that the first and second positions are described as being horizontal and vertical, respectively, for purposes of example. The disclosed IHS applies as well to other first and second positions or spatial orientations without departing from the spirit of the invention.

FIGS. **7**A-**7**B show depicts a textual representation of the disclosed coffee design process including 1) setting user preferences at set preferences block **705**, 2) conducting the design protocol at design protocol block **710**, 3) performing a total dissolved solids (TDS) measurement with a refractometer at TDS measurement block **715**, 4) correcting the brew protocol if necessary (included in block **715**), 4) saving data at block **720**, and 5) printing data at block **725**. The process also includes providing help information at block **730**. The processor further includes an "about the program" block **730** with design credits, legal notices and license key information.

FIGS. **7**A-**7**B show provides a high level overview of the coffee design process. The screen shots of FIG. **8**A-**8**J will provide more detail with respect to the coffee design process and are discussed below following discussion of the FIGS. **7**A-**7**B high level process. The user sets preferences in set preferences block **705**. More particularly, the user may select one of three different coffee design modes as a starting preference, namely: Start By Entering 1) brewing water volume

2) desired coffee yield or 3) ground coffee weight. In brewing water volume design mode, the user inputs starting brewing water volume and the desired strength (solubles concentration) % TDS as input values. In response, coffee design application **602** determines or computes the brew formula, and determines the remaining two variables, namely ground coffee weight and resulting coffee yield volume. In desired coffee yield mode, the user inputs the desired coffee yield in volume and the desired strength (solubles concentration) % TDS. In response, coffee design application **602** computes the brew formula, and determines the remaining two variables, namely the required brew water volume and ground coffee weight. In ground coffee weight mode, the user inputs the ground coffee weight and the desired strength (solubles concentration) % TDS. In response, coffee design application **602** computes the brew formula, and determines the remaining two variables, namely the required brew water volume and resulting coffee yield volume.

In set starting preferences block **705**, the user may select the starting water temperature. In one embodiment, the default starting water temperature is 55 degrees F. However, a user may select a starting water temperature between 55 and 70 degrees F. if the user is using a home brewer with bottled or tap water. The user may also select a brewing temperature in block **705**. The default brewing temperature is 201 degrees F. in one embodiment. The user may select a brewing temperature that is typically between 190 and 205 degrees F. The user may also specify temperature units in degrees F. or degrees C. in block **705**.

In set starting preferences block **705**, the user may also select target settings for the coffee brewing process. For example, the user may input a coffee target extraction (solubles yield). The default coffee target coffee extraction is 20%, but for some coffees, a user may want to target a lower value, such as 19.5%, to emphasize sweetness, or sugars content, typical of high elevation grown coffees, for example. For other coffees that lack certain types of acidic components, one may want to select a higher target extraction, such as 22%, for example, since higher solubles yield (extraction) of that particular coffee will not extract bitter components. The user may also specify an iced coffee target extraction for which the default is 19%, to emphasize sweetness. The user may also specify a finished iced coffee target TDS strength for which the default is 2% after dilution and brewing over ice. The user may also specify and input brew chart preferences such as enabling pan and zoom on the universal brewing chart (discussed below), turning on and off taste defect labels and turning on and off region labels, as well as specifying custom regions of interest by particular coffees and or consumer preference regions. In a special case, ICED Coffee final strength target is set by the user as a preference to provide the coffee design application an input for calculation of 97% ice melt (and dilution) of concentrate which starts at a concentration strength TDS of 3.8%, and ending up at 2.0% after dilution (ICE melt).

In the design protocol block **710** of the process flow of FIGS. **7**A-**7**B, the user may select or input desired starting value units. For example, for coffee yield the user may specify volume units such as milliliters, liters, fluid ounces, quarts or gallons. In another embodiment, coffee yield units may be selected as weights, rather than volume, for example, grams, kilograms, ounces or pounds. For ground coffee weight, the user may specify one of grams, kilograms, ounces or pounds. For water volume, the user may specify as milliliters, liters, fluid ounces, quarts or gallons. In an other embodiment, brew water units may be selected as weights, rather than volume, for example, grams, kilograms, ounces or pounds. In the design protocol block **710**, the user may then enter input value in the units selected in the previous step, as well as the desired strength in percent TDS. For example, in the case of coffee yield in volume, the user may specify the desired coffee yield as 2 liters, or 1.5 gallons. For ground coffee weight, the user may specify one of grams, kilograms, ounces or pounds. For water volume, the user may specify as milliliters, liters, fluid ounces, quarts or gallons. In each mode, the % TDS is also selected as in an input value. For coffee brewing protocols, brew water and coffee yield are typically measured in volume for practical reasons, due to the ease of measurement of such bulk in volume versus weight, as long as temperature (and density) are taken into account. However, in espresso, or single-serve coffee, where volumes are typically much smaller, for example, for a single-serve portion, measurements are more practical and also more accurate when specified in weight.

In the design protocol block **710**, the user may also input a selection that the start temperature is the brew temperature if desired. More particularly, the user may select a "start temperature=brew temperature" checkbox (discussed below in FIG. **8**) by checking such box if using a commercial brewer with a boiler tank or may leave the checkbox unchecked if using a home brewer with tap or bottled at 50-75 degrees F. The user may also select the desired strength preference within design protocol block **710**. The user may adjust and select the desired strength preference by moving an adjust strength slider (discussed below in FIG. **8**). The adjustable strength slider selects desired strength in total dissolved solids (TDS) percent.

The TDS range accessible by the strength slider is based on beverage type. For hot coffee, the selectable range varies from 1.0-2.0% in one embodiment. The user may select an extended strength range, such as a range between 0.40 and 2.00% in one embodiment by checking an "Extended Range" checkbox in set preferences block **705** (discussed below in FIG. **8**). Alternatively, the user may select an extended strength range, such as a range between 0.40 and 3.60% in one embodiment by checking an "Extended Range 2" checkbox in set preferences block **705** (discussed below in FIG. **8**). Extended ranges are useful for troubleshooting existing coffee brewing protocols in the field that are being evaluated to be corrected, and may not be within normal ranges, due to significant brew formula portioning errors in excess of 5-8%, for example, or excessive extraction errors, for example. In another embodiment, the user may select any extended strength range, such as a range between 3.0% and 4%, to cover a range more appropriate for coffee concentrates, such as for iced coffee, or for hot coffee to be diluted to a desired strength preference by addition of hot water to the brewed concentrate, for a single serve beverage brewer, for example. In another embodiment, the user may select any extended strength range, such as a range between 3.0% and 18%, to cover a range more appropriate for espresso, for example.

Upon selection of the desired strength preference and the other input values and selection of units, coffee design application **602** generates a brew formula curve or line which is plotted on a universal coffee brewing chart such as shown in FIG. **5**. Recall that the universal coffee brewing chart of FIG. **5** plots Percent TDS vs. Percent Extraction. The slope of the brew formula line **510** is delta TDS over delta Extraction. The Brew Formula Ratio is used to calculate point pairs using Equation 1. The plotted brew formula line takes into account the volume of water as a function of temperature, and computes the correct weight of coffee required to meet the specified brewing protocol, and the resulting finished coffee yield.

The target strength selected is plotted on the brew formula line as a small circle **515** (red point) and represents the targeted design parameters. The user then proceeds to brew the coffee using the design output parameters that coffee design application **602** generates. If the user selected brew water volume and % TDS as input conditions, coffee design application **602** then determines the resulting coffee yield volume and required ground coffee weight values corresponding to those input conditions. If the user selected desired coffee yield volume and % TDS as input conditions, coffee design application **602** then determines the required brew water volume and ground coffee weight values corresponding to that input condition. If the user selected coffee weight and % TDS as input conditions, coffee design application **602** then determines the required brew water volume and resulting coffee yield volume corresponding to those input conditions. The user then employs the particular input conditions and corresponding values to actually brew a test batch of coffee.

As part of the coffee design process of FIGS. **7**A-**7**B, the user brews a sample of the targeted design batch of coffee as specified by the input conditions and corresponding determined variable values or results. The user places a sample of the test batch into the disclosed coffee refractometer (see FIG. **10** below) to determine the total dissolved solids (TDS) % by measuring the index of refraction of the brewed coffee sample. Before using the refractometer, the user first calibrates the refractometer using distilled water. The refractometer and water should preferably be within the temperature range of 20 degrees-25 degrees C., in one embodiment. The user cools a 10-20 ml sample of the brewed coffee to between 20 degrees C. and 30 degrees C. The user places the cooled sample into the refractometer and allows 1-2 minutes for the sample and the refractometer to reach the same temperature.

After temperature stabilization, the user takes a TDS % reading, as per bock **715**. The user then enters the TDS reading into coffee design application **602**. In response, coffee design application **602** adds a large circle plot point **520** (blue point) on the same brew formula line **510** of the universal coffee brewing chart of FIG. **5** generated during the design step. The large circle (blue point) % TDS measurement shows where the current coffee batch falls on that chart relative to the intended design point **515** (small red plot point) for strength (solubles concentration) and extraction (solubles yield). After observing where the current coffee batch results appear on the universal coffee brewing chart, the user may take corrective action, if necessary, to ensure that the final coffee design for subsequent batches of coffee falls within the parameters of the desired region of interest. Such corrective action may include:

1) Under-Extraction: If the blue large circle plot point **520** (blue point) is outside of the desired region of interest, below and to the left on the brew formula line **510**, the batch was under-extracted, and likely exhibits a taste defect associated with under-developed flavors. Common causes of under-extraction are too coarse a grind, too short a contact time with water during the brew period, lack of pre-infusion or pre-infusion levels too low and/or time too short, water too hard (mineral content too high), brew temperature too low, and/or lack of even wetting or turbulence in the brew basket.
2) Over-Extraction: If the large circle plot point **520** (blue point) is outside of the desired region of interest, above and to the right on the brew formula line **510**, the batch was over-extracted, and likely exhibits a taste defect associated with over-extracted bitter flavors. Common causes of over-extraction are too fine a grind, too long a contact time with water during the brew period, pre-infusion levels too high and/or time too long, too much turbulence in the brew basket, water too soft (too low a mineral content), and/or brew temperature too high.

FIGS. **8**C, **8**E and **8**G depict screen shots of coffee design application **602** that show different startup modes that are selectable via user Startup Preferences (FIG. **8**A), with input selections and corresponding outputs and universal brew formula plotted on charts **8**B, **8**D and **8**F. More particularly, the following design modes are selectable via user startup preferences: 1) brew water volume 2) desired coffee yield and 3) ground coffee weight. The user selects one of the 3 modes as starting input variables in coffee design application **602**. In response to this selection and percent TDS as inputs, coffee design application **602** determines the remaining 2 variables as outputs. For example, if the user selects brewing water volume (and selects a % TDS) as the starting variable or mode, coffee design application **602** determines a corresponding coffee yield and coffee ground weight. Alternatively, if the user selects desired coffee yield (and selects a % TDS), then coffee design application **602** determines the required brewing water volume and coffee ground weight needed to achieve this desired coffee yield. This mode is a particularly useful and valuable tool for the coffee trade because it promotes better brewing practice. For example, typically, a brewer may be programmed to dispense water volume in units of gallons, for example one-half gallon. However, the user may be brewing into a commonly available 2.2 or 2.5 liter brewing thermos. Typical yield under these conditions will be approximately 1.7 liters, leaving 0.5 to 0.7 liters in the thermos empty. Coffee brewed in this manner will degrade more rapidly because it cools more quickly, and loses aromatic volatiles that evaporate and condense inside the empty portion of the thermos. Selecting this mode will automatically adjust the required brew water volume and ground coffee required to yield a full batch sized to the thermos is use. Using coffee design application **602**, any units of brew water volume, desired coffee yield and ground coffee weight may be selected to suit the actual conditions in the field. Alternatively, if the user selects coffee ground weight (at the desired % TDS strength) as a starting variable or mode, then coffee design application **602** determines the required brewing water volume and resulting coffee yield. This mode is particularly useful for users of pre-ground coffee packets (pillow-packs), where the user selects a fixed coffee portion and desired percent TDS (strength) and application **602** outputs the required brew water volume and resulting yield to brew to gold-cup standards.

Coffee design application **602** generates three windows that help to design and measure brewing parameters. These windows are 1) a startup preferences or brewing preferences window, 2) a main application window and a 3) universal brewing control chart. Coffee design application **602** charts parameters and provides instant feedback so that adjustments, when necessary, can be made quickly and effectively by the user.

FIG. **8**A shows a Startup Preferences window **801** that coffee design application **602** generates to enable the user to input operating modes and preferences. Preferences (including changes) are saved automatically between application sessions. The user starts a first design session using the Default Preferences. Upon entering startup preferences window **801**, the user selects a preferred design mode in the "Start by Entering" area **802** in the upper left corner of window **801**. The user selects one of the three buttons in the "Start by Entering" area **802**, namely 1) the Water Volume button **803**—Select this option to design by entering the Brew Water Volume amount. In this mode, the software determines or

calculates the ground coffee and coffee yield amounts based on user strength TDS selected. 2) the Desired Coffee Yield (Vol) button **804**—Select this option to design by entering the Desired Coffee Yield Volume; in this mode, the coffee design application software **202** determines or calculates the ground coffee and brew water amounts based on user strength TDS selected. or 3) the Ground Coffee Weight button **805**—Select this option if you are working with a fixed weight of coffee, such as a pillow pack. In this mode, the coffee design application software **202** calculates the brew water volume and coffee yield volume amounts based on user strength TDS selected. The user may select the "Start Value=Last Used" checkbox **806** if the user desires the coffee design application **602** to remember the mode and values used in the last session upon the next startup of the application.

Startup Preferences window **801** includes "Target Settings" area **807** where the user may input Hot Coffee Target Extraction % at box **808**. For standard drip brewing of coffee, this default is set to 20 percent extraction, an industry standard "starting point" applicable to a wide range of coffees. For a sweeter cup, the user may try 18.5-19.5 percent, depending on taste preferences, the particular coffee, degree of roast, and grade of grind. Note that extracting to lower targeted levels will require more coffee to achieve the same strength preference. In "Target Settings" area **807**, the user may also input the Iced Target Extraction at box **809**. For iced coffee, the default target extraction of 19% results in a sweeter cup that is significantly less bitter than a setting of 20% would provide. With higher elevation grown coffees rich in sugars, this recipe often results in a sweet tasting batch without the use of supplemental sweeteners. In "Target Settings" area **807**, the user may also input the Iced Target Strength at box **810**. For iced coffee, this is the final result of the concentrate after 95-97% all of the ice has melted at the end of the brew. The concentrate is ready to use immediately after the brew cycle has completed. Box **811** indicates the current strength % TDS) range selected for the available design and chart range. If the user selects normal range checkbox **811**A, then box **811** displays a strength range of 1.15-1.55%. If the user selects "Extended Range 1" checkbox **811**B, then box **811** displays a strength range of 0.4-2.00%. If the user selects "Extended Range 2" checkbox **811**C, then box **811** displays a strength range of 0.4-3.6%. These ranges extend the user selectable TDS strength range and also resize the Y-axis on the universal brewing control chart accordingly, and is useful for troubleshooting existing brewing protocols in the field that are out-of-range and off the universal brew chart region of interest

Startup Preferences window **801** includes "Water Temperatures" area **812** where the user may input the starting temperature of the water in the brewer at "Start" box **813** and the actual brew temperature of the water in the brewer at "Brew" box **814**. The user may select either a degrees F. or a degrees C. scale at temperature scale selection box **812**A. For example, the user should select the Brew Temp at Brew box **814** to the programmed setting of the user's brewer (usually 195-202 Deg F.) for light to medium roasted coffees, slightly lower, i.e., 195 Deg F. for dark roasted coffees. The user may enter the start temperature at Start Temperature box **813** to what may typically be in use at home, which should be equal to either TAP water temperature or room temperature (i.e., for bottled water). Using the start and brew temperatures specified, application **602** determines the actual brew water volume and ground coffee weight required to maintain the correct brew formula ratio, a common cause of error when trying to transfer brew formulas from a commercial to a home brewer for example.

Preferences window **801** further includes a "Chart Settings" area **815** for setting preferences in the universal brewing control chart that coffee design application **602** generates. In one embodiment coffee design application **602** may allow the displaying of stored or custom regions of interest for optimum balance to be overlaid onto the universal brewing control chart. Coffee taste preference "regions" have been previously defined by different organizations (i.e. Midwest Research Institute (MRI), Coffee Brewing Center (CBC), Norwegian Coffee Center (NCC) as the "Optimum Balance" regions, or, as shown, other custom regions may be added to the chart based on individual preferences found to be appropriate for particular coffees, roast styles, and or customer surveys. Such custom regions need not be rectangular, as shown, but may be any shape including three dimensional, exhibiting preferences in percentile categories. Selecting the "Show Region Labels" checkbox **816** instructs coffee design application **602** to generate a label identifying the region of interest. Selecting the "Show Taste Labels" checkbox **817** instructs the coffee design application **602** to generate a Universal Brewing Control Chart that displays taste defect labels (i.e., bitter or under-developed). Selecting the "Enable Zoom/Pan" checkbox **818** instructs coffee design application **602** to generate a Universal Brewing Control Chart on which the user may use mouse and/or trackpad controls to zoom/pan the Universal Brewing Control Chart along with its axis. The final universal brewing control chart as configured, plotted and labeled may be saved in any commonly available formats (such as jpeg, png, bmp, emf, gif, tif), emailed, entered into a database, electronically shared, and or printed on demand. Upon completion of entering input preferences and settings in startup preferences window **801**, the user may select Done box **819**.

After the Startup Preferences have been selected as described above, the user completes the brewing protocol design process in the coffee design application **602** in the Main Application Window shown in FIG. **8**C. More details on using the Main Application Window discussed below with reference to FIG. **8**C. However, before discussion Main Application Window in detail, it is helpful to first discuss the Universal Brewing Control Chart of FIG. **8**B that coffee design application **602** produces. Coffee design application **602** performs all calculations and plots a brewing control chart dynamically and in real time as you change the % TDS strength preference slider control. Coffee design application **602** converts between different types of units instantly and accurately, and allows for mixed units (i.e., brew water in gallons, coffee yield in liters). Coffee design application **602** draws a custom brew formula line on a universal brewing control chart using any combination of selected units in weight and or volume, without restrictions to fixed portions. Application **602** also provides a relative indication of designed recipe to the measured results, in reference to a number of internationally recognized "optimum" brewing ranges. Application **602** further provides a means to troubleshoot current brewing protocols, measure and plot results which immediately identify portioning and extraction errors, and provides a means to correct them. The appearance of the Main Design Window of FIG. **8**C depends on the variable the user selected to enter as the INPUT data in the Startup Preferences window **801** of FIG. **8**A. Coffee design application **602** displays the computed OUTPUT data immediately below in the next group box of the window, and plots the results on the Universal Brewing Control Chart dynamically and in real time in a charting window seen in FIG. **8**B. The completed data and universal brewing control chart as configured, labeled and plotted on the Main Application Window

may be saved, recalled, electronically shared, printed or emailed. Each "recipe" may be stored separately, or in one embodiment of the application **602**, as part of a database residing within the application or as part of a shared networked database application.

FIG. **8**B shows a universal coffee brewing control chart **820** that includes a representative coffee brew formula line **821**. The Universal Brewing Control Chart plots the actual design point **822** (small circle) and measured results **823** (large circle) from input data and % TDS measurements from the disclosed coffee refractometer. FIG. **8**B shows a typical universal coffee brewing control chart **820**, taken from the brew formula discussed below.

FIG. **8**B shows the desired brew formula line as brew formula line **821**. The brew formula line **821** represents the ratio (17.08:1) of water to coffee by weight used to brew the coffee. The resulting TDS of the brewed coffee will be determined by the brew formula, as well as other factors (temperature, grade of grind, dwell time, and turbulence). The final % TDS measurement **823** may then be followed down to the X-axis, to see how close the results (19.8%) came to the design target extraction (20.0%). The small circle **822** on the Brew Formula line shows the selected strength design target at the default extraction (20%). The larger circle **823** on the brew formula line **821** shows the actual resulting extraction and strength determined by measuring and inputting the TDS % of the brewed coffee into coffee application **602** as a total dissolved solids measurement. The actual resulting extraction and strength are plotted as a result of the TDS % measurement on a specialized coffee refractometer disclosed and discussed below in more detail.

Universal brewing control chart **820** includes a number of coffee design target regions of interest. Chart **820** shows the George Howell Coffee Company (GHCC) suggested target region of interest as region of interest **824** for optimum balance. Chart **820** also shows a Midwest Research Institute region of interest **825**. Chart **820** further shows a target region of interest **826** defined by the Norwegian Coffee Center.

FIG. **8**C shows the main application window **827** of coffee design application **602**. As discussed above, depending on the initial preference settings, application **602** may be used to design coffee brew processes by a 1) a water volume mode, 2) a coffee yield mode or 3) a ground coffee mode. Planning a brew from the starting water volume is now discussed, namely the water volume mode. The Startup Preferences discussed earlier set up the main window for this water volume mode, including brew water temperature to match the brewer boiler setting in use. The brew water volume is first calibrated, according to the brewer manufacturer specifications, to dose correctly the amount of water programmed as the starting brew water volume. The user then performs the following coffee design steps:

1. Select Hot Coffee in the Beverage Type drop-down menu **828** in the lower left-hand corner of main application window **827**.
2. Enter the preferred Brew Water units in the drop-down menu **829** next to the Water Volume field **830**, and enter the Water Volume in the Water Volume field **830**. For example, the user may enter a brew water volume value of 0.50 gal. in Water Volume field **830**.
3. Select the preferred Strength TDS % with the slider **831** on the window's left side. In response to the above described user design inputs, application software **602** determines the brew formula and the corresponding required Ground Coffee weight and final Coffee Yield. Coffee design application **602** then displays the determined Ground Coffee weight at Ground Coffee weight box **833** and displays the final Coffee Yield at Coffee Yield box **832**. Final values, including the brew formula ratio, are also displayed in the legend of the brewing control chart. The units are selectable by the user at units select boxes **834** and **835**. In this example, the resultant yield is 56.52 fl oz (US) and the ground coffee weight is 3.75 oz (wt.) The coffee design application **602** draws the brew formula curve **821** as seen in the universal coffee brewing control chart of FIG. **8**D. Coffee design application **602** also plots the target Strength TDS **822** at the pre-set target extraction of 20%.
4. If not done earlier, the user may enter the preferred units of measure in the two output fields, namely Coffee Yield volume **834** and Ground Coffee weight **835** of FIG. **8**C. Alternatively, the user may convert these units to any desired units using boxes **834** and **835**.
5. After brewing in accordance with the above parameters, the user may test the total dissolved solids (TDS) using the disclosed coffee refractometer. The user may enter the measured % TDS in the Dissolved Solids Measurement field **836** after selecting TDS % at box **837** as the instrument readout mode. Alternatively, coffee design application **602** will provide a conversion estimate for TDS % using box **837** that may be set to ppm or BRIX if another TDS instrument or refractometer provides readings in those units.
6. The user may use a File>Save menu selection to save the brew formula, chart and portion plan, and may print the same if desired.

To summarize, in the above example, beverage type was set to Hot Coffee, brew water volume was set to 0.50 gallons, and the strength slider **831** was set to 1.3% as the desired coffee strength. Coffee design application **602** determines the brew formula ratio, the required ground coffee in oz-wt and the resulting brewed coffee yield in fl-oz volume. Brew temperature was the same as start temperature at 201 Deg F.

FIG. **8**E shows the main application window **827** of coffee design application **602**. As discussed above, depending on the initial preference settings, application **602** may be used to design coffee brew processes by a 1) a water volume mode, 2) a coffee yield mode or 3) a ground coffee mode. Planning a brew by specifying the second mode, namely, coffee yield as input, is now discussed as coffee yield mode.

Traditionally, brew formulas have been developed using a pre-set volume of brew water as part of the brew recipe. For example, a one (1) gallon batch meant setting the brewer for one gallon of brew water, and using approximately 7.5 ounces coffee (i.e., the gold-cup standard for 1.3% TDS). However, this method results in a final yield of approximately 112-fluid ounces, leaving about 16-fl oz empty in the brewing vessel. In the Desired Yield mode, the disclosed coffee design application **602** enables the user to specify one (1) gallon of finished coffee to fill the brewing vessel completely. In one embodiment, coffee design application **602** determines exact portions of brew water and ground coffee required, for example 1.13 gallons of brew water and 8.5 ounces of coffee. This design mode allows the user to specify the finished yield needed to fill a brewing thermos, rather than leave a significant percentage empty. Units can be mixed in any combination (brew water in gallons, yield in liters), and coffee design application **602** determines the required results in the units specified. For example, for a 2.5 liter thermos, 0.75 gallons brew water and 5.6 ounces of coffee will yield exactly 2.5 liters of finished coffee. To ensure accurate portions of water and coffee, coffee design application **602** takes into account the water lost in the spent basket and the volume of water required as a function of temperature. The brew basket refers

to a vessel (not shown) that holds coffee grounds in the correct depth and area in the brewer for proper wetting and extraction during the coffee brewing process. The user selects Startup Preferences window **801** of FIG. **8**A and then selects Desired Coffee Yield button **804**. The user returns to the main application window **827** of FIG. **8**E and enters the desired coffee yield into Desired Coffee Yield box **830** as shown in FIG. **8**E. The user may then follow the coffee design method steps below:

1. Set the Beverage Type drop-down menu **828** [in the lower left corner of main application window **827**] to select the Hot Coffee charting range.
2. Select the preferred units of measure of the Desired Yield in the drop-down menu **829** next to the Desired Yield field box **830**, and enter the Desired Yield for the finished coffee in Desired Yield field box **830**. For example, the user may select liters in box **829** and 2.35 in box **830**.
3. Select the preferred units of measure if necessary for the two calculated fields at Brew Water Volume unit selection box **834** and Ground Coffee Weight unit selection box **835**. In this particular example, coffee design application **602** determines the required Brew Water Volume in liters and the Ground Coffee weight required in grams. When using a commercial brewer, the user should check Start=Brew Temperature box **838** to indicate that the starting temperature is equal to the brewing temperature.
4. Select the preferred Strength with the slider **831**. For example, the user may select a strength of 1.27 TDS % in this example.
5. After brewing a batch of coffee under the input conditions above, the user may measure the total dissolved solids in the batch of coffee from a sample thereof. The user places a sample of the brewed batch in the disclosed coffee refractometer discussed in more detail below. The coffee refractometer measures Total Dissolved Solids in percent (%). The user takes a TDS reading from the coffee refractometer and enters the measured % TDS in the "Enter Dissolved Solids Measurement" field or box **836**.
6. Use the File>Save menu selection to save the brew plan, and print if desired.

This "Desired Coffee Yield" design mode facilitates better coffee brewing practice in a number of ways. For example, in this design mode, application **602** determines or calculates the coffee and water portions required to nearly fill the brewing vessel completely. This mode also reduces the amount of air in a thermos or other coffee brew receptacle, and reduces the loss of aroma producing volatiles, while increasing the volume of hot coffee brewed. The additional thermal mass of coffee keeps the thermos hot longer, and can increase hold times by up to 10-15 minutes per batch. This mode may also reduce the frequency of brewing, making a coffee brewing operation more efficient. This mode may allow brewing larger batches that inherently reduces portioning errors. In the "Desired Coffee Yield" design mode in the example of FIG. **8**E, the Beverage Type is set to Hot Coffee at Beverage Type drop down menu **828**, and Desired Yield is set to 2.35 Liters in boxes **830**, **832** for a 2.5 Liter Thermos receptacle. Strength slider **831** is set to 1.27% TDS. The disclosed coffee refractometer is used to test a sample of the brewed coffee. In this example, the coffee refractometer measures a TDS value of 1.3%, which is entered by the user at Enter Dissolved Solids Measurement input box **836**. In response to entering the TDS value, coffee design application **602** plots a universal coffee brewing control chart **820'** as shown in FIG. **8**F. Universal coffee brewing control chart **820'** shows the brew formula, namely a brew formula line **821'**, as a brew formula ratio of 17.56 to 1. Coffee design application **602** plots a small circle **822'** that indicates the selected strength coffee design target at the default extraction (20%). The larger circle **823'** on brew formula line **821'** indicates the actual resulting extraction and strength determined by measuring the TDS % of the brewed coffee sample with the disclosed coffee refractometer and inputting the measured TDS % into coffee design application **602** as a total dissolved solids measurement. Since the measured coffee results are within 0.5% of the target extraction (solubles yield) of the design target, no further adjustment is required in this example. The final coffee design recipe values are also shown in the chart Legend **840**, at the bottom of the chart **820'**.

FIG. **8**G shows the main application window **827** of coffee design application **602**. As discussed above, depending on the initial preference settings, application **602** may be used to design coffee brew processes by a 1) a water volume mode, 2) a coffee yield mode or 3) a ground coffee mode. Planning a brew by specifying the third mode, namely ground coffee weight as input, is now discussed as ground coffee weight mode.

Design by ground coffee weight is a commonly used in high volume feeder establishments using pre-measured, pre-ground pillow packs. While it is not preferable to pre-grind coffee for freshness reasons, this mode is provided to address such feeder establishments, so they can improve their coffee brewing practices to internationally accepted standards.

The user selects Startup Preferences window **801** of FIG. **8**A and then selects Ground Coffee Weight button **805**. The user returns to the main application window **827** of FIG. **8**G and enters the ground coffee weight into ground coffee weight box **830** as shown in FIG. **8**G. For example, if the weight of a pre-ground coffee pillow pack is 3.5 oz, then the user selects the unit ounces in unit selection box **829** and inputs 3.5 into box **830** as shown. The user may then follow the coffee design method steps below:

1. Select Hot Coffee in the Beverage Type drop-down menu **828** in the lower left corner of main application window **827**.
2. Select the preferred unit of measure in the drop-down menu **829** next to the Ground Coffee field **830**, and enter the weight in the Ground Coffee field **830**.
3. Select the preferred units of measure if necessary for the two calculated fields, namely Brew Water Volume and Yield. Coffee design application **602** determines or calculates the required Brew Water Volume and the final coffee Yield volume in the units selected. Start Temperature=Brew Temperature is checked at checkbox **838**.
4. Select the preferred Strength with the slider **831**. In this example, the user engages slider **831** to select a strength of 1.3%.
5. After brewing coffee in accordance with the determined parameters, the user then employs the disclosed coffee refractometer to measure the total dissolved solids, TDS, of a sample of the brewed coffee. The user enters the measured % TDS in the Enter Dissolved Solids Measurement field **836**.
6. Use the File>Save menu selection to save the brew plan, and print if desired.

This example illustrates how to design to desired strength protocols using fixed ground coffee packets by weight. Coffee design application **602** calculates the required brew Water Volume and Yield volume of coffee in the units selected. The Beverage Type drop-down menu **828** was set to Hot Coffee. Ground Coffee was set to the packet size of 3.5 ounces

weight. Strength slider was set to 1.30% TDS. Dissolved Solids were measured and entered at 1.3%

Coffee design application **602** draws a universal coffee brewing control chart **820"** as shown in FIG. **8**H. In FIG. **8**H, box **824"** represents the desired target region and line **821"** represents the particular brew formula ratio, namely 17.19 to 1, in this particular example that employs 0.47 gallons of water and 3.5 oz (wt) of coffee to brew a batch of coffee. Small circle **822"** represents the desired design point on brew formula line **821"**, while large circle **823"** represents the actual coffee design point determined in response to the measured TDS % of the brewed coffee batch measure in the disclosed coffee refractometer. Region **824"** is the particular region of interest on the brew control chart of FIG. **8**H. This design mode is useful for users of pre-ground and pre-weighed fixed packs of ground coffee wishing to improve their coffee brewing protocols by providing a means to reprogram their brewers to brew to gold-cup standards, even though fixed weight packs have been provided.

FIG. **8**I shows the main application window **827** of coffee design application **602** which is also useful in designing coffee concentrates. This example shows an iced coffee design, where the user selects iced coffee in Beverage Type drop-down menu **828**. The coffee design application **602** will design coffee extraction protocols for Iced Coffee Concentrate, to be brewed fresh and directly over ice. Coffee design application **602** calculates coffee concentrate TDS strength both before and after ice is melted. The process is designed to allow approximately 95% to approximately 97% percent of the ice to melt at brew completion time, so that the finished concentrate is cold, and ready to serve immediately after brewing. In one embodiment, the complete brewing cycle takes only 5-6 minutes, typically. Care should be taken using this mode to choose portions that will not overload nor overflow the brew basket. For example, a 0.5-1.0 gallon brewer may be able to brew 7-9 ounces of ground coffee, but could overflow the brew basket if more ground coffee is used. Generally, a 1.5 gallon brewer can accommodate up to 12-14 ounces ground coffee. Design by coffee weight mode is supported in this embodiment, to ensure such limitations are adhered to, and application **602** determines the required brew water volume, concentrate yield, and weight of ice required. In this example, the user sets the coffee brew strength to 3.8% using slider **831**. The user employs brew water volume as the starting value in Enter Starting Value box **830**. The units are gallons in unit selection box **829**. In this example, it is assumed that a typical 1.5 gallon brewer is being used. The brewer is programmed to dispense 0.7 gallons, yielding approximately a half-gallon (0.49 gal) of coffee at 3.7% TDS. The coffee is brewed into an open top container containing 62 ounces-weight of ice, then stirred and covered. The resulting concentrate is after serving over ice in a glass filled two-thirds will be about 1.5-1.8% TDS. Total concentrate yield is just under one gallon. This serves approximately sixteen 16-oz servings (7.5 fl oz concentrate over approximately 8 oz-wt ice). Coffee design application **602** plots the resultant brew formula ratio curve **821'"** as seen in FIG. **8**J. Coffee design application **602** also plots the target coffee design point as small circle **822"**. After the user measures the total dissolved solids TDS % with the disclosed coffee refractometer and inputs the TDS % value, for example 3.7%, in box **836**, application **602** plots the actual coffee design point at large circle **823'"** on brew formula ratio line **821'"**.

FIG. **9**A is a flowchart that shows process flow in the methodology that the disclosed information handling system **600** employs. In one embodiment, when loaded into system **600**, coffee design application **602** of computer program product **608** enables system **600** to carry out this methodology. System **600** asks the user to select from the following design coffee modes: 1) brew water volume mode 2) desired coffee yield mode and 3) ground coffee weight mode, as per block **900** of the flowchart of FIG. **9**A. System **600** asks the user to select a coffee target extraction percent, as per block **902**. System **600** receives the user's coffee target extraction percent selection as input to the coffee design process.

System **600** asks the user to set the starting water temperature and the brewing water temperature, as per block **904**. System **600** receives the user's starting water temperature and brewing water temperature as inputs to the coffee design process. System **600** queries the user to determine if the starting temperature equals the brewing temperature, as per block **906**. System **600** queries the user to select a beverage type, namely hot coffee, iced coffee or in another embodiment, espresso, as per block **908**. The Beverage Type drop-down menu pre-sets **828** are used to adjust the brewing and chart areas of solubles concentration (% TDS Strength) and solubles yield (% Extraction) to the appropriate ranges commonly used for brewing the selected types of beverage(s). System **600** receives the user's Beverage Type selection as input to the coffee design process. System **600** presents a slider tool **831** to the user to enable the user to select a design coffee strength, as per block **910**. For example, the user may select a strength of 1.3% with the slider tool, or may also use arrow keys, touch screen controls or other methods for setting the input value. System **600** receives the user's selection of coffee strength as input to the coffee design process.

System **600** determines the brew formula ratio using 1) weight of water, determined from the volume of the water at the prescribed brewing temperature 2) the target extraction percent % solubles yield) and 3) the design TDS target strength (% solubles concentration) from the slider control (i.e. coffee strength), as per block **912**. The final brew formula ratio is equal to the weight of water divided by the weight of coffee as determined by the above parameters, and remains the same regardless of the brew batch size. System **600** generates a universal control chart graph including a grid showing TDS range (%) on the y axis vs. coffee extraction (%) on the x axis, as per block **914**. Using the brew formula ratio determined in block **912**, system **600** plots and displays on the universal control chart graph the brew formula line that represents the brew formula ratio.

System **600** performs tests to determine if the user selected 1) brew water volume mode, 2) desired coffee yield mode, or 3) ground coffee weight mode at decision blocks **918**, **920** and **922**. If the user selected 1) brew water volume mode, then process flow continues to the brew water volume module of FIG. **9**B, as per block **924**. If the user selected 2) desired coffee yield mode, then process flow continues to the desired coffee yield mode of FIG. **9**C, as per block **926**. If the user selected 3) ground coffee weight mode, then process flow continues to ground coffee weight module of FIG. **9**D, as per block **928**.

FIG. **9**B shows process steps that system **600** performs when the user selects the brew water volume mode. In one embodiment, coffee design application **602** instructs system **600** to carry out these process steps. System **600** asks the user to select brew water volume units, as per block **930**. In one embodiment, this is achieved by a pull-down menu or unit selection box with different volume unit selections. System **600** receives the user's brew water volume unit selection as input to the coffee design process. System **600** also asks the user to select the brew water volume, as per block **932**. System **600** receives the selected brew water volume as input to the coffee design process. System **600** asks or allows the user

to select units for the coffee yield variable that the system determines in response to user input, as per block **934**. The selected units may be milliliters, liters, fluid ounces, quarts or gallons, for example. Coffee yield is a determined or calculated variable that is a function of user input selections. System **600** asks or allows the user to select units for the ground coffee weight variable that the system determines in response to user input, as per block **936**. The selected units may be grams, ounces or pounds, for example. Ground coffee weight is a determined or calculated variable that is a function of user input selections.

System **600** converts the selected volume and weight units to predetermined internal standard units (e.g. metric units) before performing variable determinations in response to user input, as per block **938**. Calculations are performed within system **600** in these standard units and then converted later to the units selected by the user for display purposes. System **600** determines the ground coffee weight variable using 1) brew water weight 2) water density at brew temperature 3) target extraction percent and 4) design TDS from the strength input slider, as per block **940**. More particularly, coffee design application **602** of system **600** employs EQUATION 2 to determine the coffee weight variable:

coffee weight(g)=water weight(g)/(E %*(1/*TDS*%−0.01)+waterdensity@brew temp(g/ml)*water-Lost(ml/g) Equation 2

wherein E % is Extraction percent. System **600** converts the determined ground coffee weight variable to the user-selected units and displays the result, as per block **942**.

System **600** determines the brew water volume lost at brew temperature using the coffee weight, as per block **944**. System **600** determines the coffee yield volume variable using 1) the brew volume at the start temperature, 2) water density at the start temperature, 3) water density at the brew temperature, and 4) brew volume lost at brew temperature, as per block **946**. More particularly, coffee design application **602** of system **600** employs EQUATIONS 3 to determine the coffee yield volume variable:

1) Volume Lost_at__*T*brew(ml)=waterLost(ml/g)*coffee weight(g)

2) Yield volume(ml)_at__*T*brew=water_volume(ml)_at__*T*start* Density(g/ml)@startTemp/Density(g/ml)@brewTemp—volume Lost_at__*T*brew(ml); Equation 3

System **600** converts the determined coffee yield volume to the user-selected units and displays the results, as per block **948**. The user or other entity then brews coffee using the specified parameters and determined variables or results, as per block **950**. The user, other entity or apparatus measures the actual total dissolved solids that the resultant brewed coffee exhibits, as per block **952**. For example, the disclosed coffee refractometer may determine the TDS % that a sample of the brewed coffee exhibits. System **600** displays the actual TDS reading on the universal brewing control chart graph, as per block **954**. For example, circle **823** of the universal brewing control chart graph of FIG. **8**B shows such a display of actual TDS results. Process flow continues back to the select design mode block **900** of FIG. **9**A. The user may then again select any coffee design mode desired.

FIG. **9**C shows process steps that system **600** performs when the user selects the desired coffee yield mode. In one embodiment, coffee design application **602** instructs system **600** to carry out these process steps. System **600** asks or allows the user to select desired coffee yield units, as per block **960**. In one embodiment, this is achieved by a pull-down menu or unit selection box with different desired coffee yield unit selections. System **600** receives the user's desired coffee yield unit selection as input to the coffee design process. System **600** also asks the user to select the coffee yield, as per block **961**. System **600** receives the selected coffee yield volume as input to the coffee design process. System **600** asks or allows the user to select units for the brew water volume variable that the system determines in response to user input, as per block **962**. The selected units may be milliliters, liters, fluid ounces, quarts or gallons, for example. Brew water volume is a determined or calculated variable that is a function of user input selections. System **600** also asks or allows the user to select units for the ground coffee weight variable that the system determines in response to user input, as per block **963**. The selected units may be grams, ounces or pounds, for example. Ground coffee weight is a determined or calculated variable that is a function of user input selections.

System **600** converts the selected volume and weight units to predetermined internal standard units (e.g. metric units) before performing variable determinations in response to user input, as per block **965**. Calculations are performed within system **600** in these standard units and then converted later to the units selected by the user for display purposes. System **600** determines the ground coffee weight variable using 1) coffee yield volume at brew temperature 2) brew formula ratio 3) water density at room temperature, as per block **966**. More particularly, coffee design application **602** of system **600** determines the ground coffee weight variable using EQUATION 4:

coffee(g)=water weight(g)/*BF* Equation 4

System **600** converts the determined ground coffee weight variable to the user-selected units and displays the result, as per block **967**.

System **600** determines the brew water volume lost at brew temperature using the coffee weight, as per block **968**. System **600** determines the brew volume at start temperature variable using 1) coffee yield volume at brew temperature, 2) brew volume lost at brew temperature, 3) water density at the brew temperature, and 4) water density at the start temperature, as per block **969**. More particularly, coffee design application **602** of system **600** determines the brew volume at start temperature variable using EQUATION 5:

water volume(ml)@*T*start=(yield_vol(ml)@__*T*brew+VolumeLost_at__*T*brew(ml))* Density(g/ml)@brewTemp/Density(g/ml)@startTemp; Equation 5

System **600** converts the brew volume at start temperature to the user-selected units and displays the results, as per block **970**. The user or other entity then brews coffee using the specified parameters and determined variables or results, as per block **971**. The user, other entity or apparatus measures the actual total dissolved solids that the resultant brewed coffee exhibits, as per block **972**. For example, the disclosed coffee refractometer may determine the TDS % that a sample of the brewed coffee exhibits. System **600** displays the actual TDS reading on the universal brewing control chart graph, as per block **973**. For example, large circle **823'** of the universal brewing control chart graph of FIG. **8**F shows such a display of actual TDS results. Process flow continues back to the select design mode block **900** of FIG. **9**A, as per block **974**. The user may then again select any coffee design mode desired.

FIG. **9**D shows process steps that system **600** performs when the user selects the ground coffee weight mode. In one embodiment, coffee design application **602** instructs system **600** to carry out these process steps. System **600** asks or

allows the user to select desired ground coffee weight units, as per block **980**. In one embodiment, this is achieved by a pull-down menu or unit selection box with different desired coffee ground weight unit selections. System **600** receives the user's desired ground coffee weight unit selection as input to the coffee design process. System **600** also asks the user to select the ground coffee weight, as per block **981**. System **600** receives the selected ground coffee weight as input to the coffee design process. System **600** asks or allows the user to select units for the brew water volume variable that the system determines in response to user input, as per block **982**. The selected units may be milliliters, liters, fluid ounces, quarts or gallons, for example. Brew water volume is a determined or calculated variable that is a function of user input selections. System **600** also asks or allows the user to select units for the coffee yield volume variable that the system determines in response to user input, as per block **983**. The selected units may be milliliters, liters, fluid ounces, quarts or gallons, for example. Coffee yield volume is a determined or calculated variable that is a function of user input selections.

System **600** converts the selected volume and weight units to predetermined internal standard units (e.g. metric units) before performing variable determinations in response to user input, as per block **984**. Calculations are performed within system **600** in these standard units and then converted later to the units selected by the user for display purposes. System **600** determines the brew water volume variable using 1) coffee weight 2) target extraction percent 3) design TDS from strength input slider, as per block **985**. More particularly, coffee design application **602** of system **600** determines the brew water volume variable using EQUATION 6:

water volume(ml)=water volume lost(ml)* Density(g/ml)@brewTemp/Density(g/ml)@startTemp+ [coffee weight(g)*E %* (1/*TDS*%−0.01)]/Density(g/ml)@startTemp Equation 6

System **600** converts the determined brew water volume variable to the user-selected units and displays the result, as per block **986**.

System **600** determines the brew water volume lost at brew temperature using the coffee weight, as per block **987**. System **600** determines the coffee yield volume variable using 1) brew volume at start temperature, 2) water density at start temperature, 3) water density at the brew temperature, and 4) brew volume lost at brew temperature, as per block **988**. More particularly, coffee design application **602** of system **600** determines the brew water volume lost at brew temperature variable using EQUATION 7:

yield volume(ml)@brewTemp=water_volume(ml)@startTemp* Density(g/ml@startTemp/Density(g/ml)@brewTemp−volumeLost@brewTemp(ml); Equation 7

System **600** converts the coffee yield volume to the user-selected units and displays the results, as per block **989**. The user or other entity then brews coffee using the specified parameters and determined variables or results, as per block **990**. The user, other entity or apparatus measures the actual total dissolved solids that the resultant brewed coffee exhibits, as per block **991**. For example, the disclosed coffee refractometer may determine the TDS % that a sample of the brewed coffee exhibits. System **600** displays the actual TDS reading on the universal brewing control chart graph, as per block **992**. For example, large circle **823"** of the universal brewing control chart graph of FIG. **8**H shows such a display of actual TDS results. Process flow continues back to the select design mode block **900** of FIG. **9**A, as per block **993**. The user may then again select any coffee design mode desired.

Returning again to the small form factor or hand-held information handling system (IHS) **675** of FIG. **6**B, it is noted that IHS **675** receives user input in one spatial orientation or position and outputs results to its display **690** when the user moves or changes the IHS to a second spatial orientation or position. More specifically, the user may use touch screen display **690** to make user selections and provide other input while IHS **675** is in the first position. For example, the user employs touch screen display **690** to select startup preferences such as selecting one of multiple design modes, namely 1) brewing water volume mode, 2) desired coffee yield mode, and 3) ground coffee weight mode. The user may also make other input selections shown in startup preferences of FIG. **8**A while IHS **675** is oriented in the first spatial orientation. In response to such input and when the user changes the spatial orientation of the IHS to a second spatial orientation, coffee design application **602** draws a universal brewing control chart such as shown in FIGS. **8**B, **8**D, **8**F, **8**H and **8**J on display **690**. The displayed universal control chart displays the results of user input which may include a TDS % reading from the disclosed refractometer for a brewed coffee sample that is brewed in accordance with the coffee design parameters that coffee design application **602** determines.

In one embodiment, to complete the final plot point on the universal brewing control chart, the actual measured % TDS may be entered when IHS **675** is in either the first or second spatial position. For example, the measured % TDS from the disclosed coffee refractometer may be entered on touch screen display **690** on either the universal brewing control chart on the display while the IHS exhibits the second orientation (such as vertical) or the Main Application window while the IHS exhibits the first orientation (such as horizontal) by using extended touch screen commands that appear on the universal brewing control chart, for example, as buttons or data entry boxes, in a visible layer behind the partially transparent displayed chart.

Generally, IHS **675** receives the user's input selections while IHS **675** exhibits the first spatial orientation while coffee design application **602** receives the first position signal from sensor package **680**. When coffee design application **602** of IHS **675** receives the second position signal, indicating that the user has changed the orientation of the IHS **675** to the second spatial orientation, coffee design application **602** senses this signal change and in response determines or calculates the solution to the user inputs, including but not limited to the brew formula, required portions of coffee and water, and draws a universal brewing control chart on display **690**.

Specific recipes for any number of brew formula sessions may be stored in the IHS **675** as an integrated database in non-volatile memory **679**, and or transmitted to a database via any of a number of wireless protocols, including web-based sharing protocols, or electronically mailed to other users to share, and interactively modify, for example, based on a collaborative approach to establishing a desired brewing protocol. Such recipes may be used to control brewing protocols for an entire installed base of brewing equipment, such equipment being programmable manually or automatically to execute said protocol(s), through a manual, wired or wireless interface, for example, for feeder establishments wishing to maintain a high quality coffee brewing program to ensure consistency from cup-to-cup across its entire installed base of restaurants, cafes or coffee bars.

FIG. **10**A shows the disclosed refractometer **1000** that is usable to measure TDS % of a brewed coffee sample by determining the index of refraction of the brewed coffee sample. Refractometer **1000** includes a light source **1005**

such as a yellow semiconductor laser that generates 589 nm light in one embodiment. An illumination lens **1010** directs the light from light source **1005** toward prism **1015** as shown. Prism **1015** receives incident light **1017** from light source **1005** as shown. Prism **1015** is a transparent material that exhibits an index of refraction "n_p". The user or other entity or apparatus places a coffee brew sample **1020** on prism surface **1025** in preparation for measurement of the index of refraction "n_s" that the brew sample **1020** exhibits.

A collection lens **1030** collects light **1032** refracted or reflected by the prism sample interface **1034** and directs that light to a linear photo detector **1035**. The purpose of the illumination lens **1010** is to direct light from light source **1005** to prism **1015**. More specifically, the purpose of illumination lens **1010** is to form a focusing beam or cone of light incident upon the prism-sample interface **1034** that ranges in angles of incidence between a minimum angle of incidence, θ_{min}, and a maximum angle of incidence, θ_{max}. The angle of incidence is measured relative to the normal surface **1027** which is perpendicular to the prism surface **1025**. In one embodiment, the critical angle q_c of the prism-sample interface **1034** should be such that $\theta_{min}<\theta_c<\theta_{max}$. A unique property of the critical angle is that for all angles larger than than θ_c, 100% of the light is reflected from the interface **1034** and none transmits. For angles inside of the prism **1015** that are less than θ_c, some light transmits into the sample material **1020** and therefore less than 100% of the light is reflected. In other words, for all rays in the beam of light generated by illumination lens **1010** that are focused in the prism to an incident angle greater than the critical angle θ_c, 100% of the light is reflected off of the prism-material interface **1034** and propagates towards the collection lens **1030** and then on to the linear detector **1035** or photodetector. The light ray that is incident upon the prism-sample interface **1034** at θ_c will strike the linear detector **1035** at a point $x=x_c$. By analyzing the detected light levels from $x=0$ to $x=x_{max}$ on the detector **1035**, the firmware **1047** or software of the refractometer detects the position x_c since for $x_c<x<x_{max}$, the light level is substantially constant across the detector array **1035**. With a well-calibrated refractometer, the detector position x_c is mapped back to a critical angle θ_c, which from EQUATION 8 below and knowing the index of refraction of the prism n_p, the index of refraction n_s of the sample can be determined and displayed or otherwise reported.

$$\theta_c=\arcsin(n_s/n_p) \qquad \text{Equation 8}$$

Therefore, in refractometer **1000** the index of refraction of the prism **1015** must satisfy $n_p>n_s$ for all values of n_s desired to be measured in order for a critical angle θ_c to exist. Given the range of θ_c resulting from the range of n_s to be measured, the illumination lens **1010** arrangement is designed to include this range of angles relative to the surface normal **1027** of surface **1025**. Similarly, the collection lens **1030** is designed such that the range of angles θ_c are linearly mapped to positions x on the linear detector array **1035**. By way of example, for a refractometer designed to operate with a sugar solution between 0 and 10° BRIX at 20° C., one requires the ability to detect indices of refraction ranging from 1.3330 to 1.3479. Using a source with a wavelength of λ_0=589 nm and a prism made of BK7 (n_p=1.5167 @λ_0), the range of critical angles to detect are θ_c=61.50° to 62.71°. Choosing an Eastman Kodak (Rochester, N.Y.) linear CCD array model KLI-2113 with an array of 2098 pixels for linear detector **1035**, the theoretical resolution is 7E-6 in index of refraction and 0.005° BRIX. In addition to being wavelength sensitive, the index of refraction for any material changes slightly with temperature. For water at 20° C. (68° F.) the index of refraction is 1.333 and changes by −0.0001 for every degree C. The disclosed coffee refractometer includes automatic temperature compensation as described in more detail below.

Refractometer **1000** includes a microcontroller **1045** with control firmware **1047** or control software therein. Microcontroller **1045** includes a memory store **1049** for storage of information and data. Refractometer **1000** also includes a temperature sensor **1050** near the prism-sample interface **1034** of prism **1015**. Temperature sensor **1050** couples to an input of microcontroller **1045** to inform microcontroller **1045** of the current temperature of the prism-sample interface **1034**. A control line **1055** couples microcontroller **1045** to light source **1005** to enable microcontroller **1045** to control light source **1005**. Refractometer **1000** also includes a display **1060** to allow refractometer **1000** to display measurement results such as a TDS % value of the brew sample **1020**. Refractometer **1000** further includes a network interface **1065** that enables refractometer **1000** to connect via wire or wirelessly to other information handling systems **600** or the Internet **1070**. Information handling system **600** may include coffee design application **602** which uses the TDS % coffee brew sample result from the refractometer **1000** as input for coffee design universal control chart display purposes.

FIG. **10**B is a block diagram of a brewing station **1075** that employs the disclosed coffee design system **600** and the disclosed coffee refractometer **1000**. In one embodiment, coffee brewing station **1075** includes a hot water supply **1076** and a brew basket assembly **1077** where coffee grounds mix with hot water to form a coffee drink. As the coffee drink exits brew basket **1077**, the coffee drink flows downward into a vessel **1078** that captures the brewed coffee. Vessel **1078** dispenses brewed coffee to coffee pot **1079** or other container suitable for transporting of the brewed coffee to the coffee drinker. In one embodiment, a coffee refractometer **1000** is situated in vessel **1077** so that refractometer **1000** may determine the TDS reading of a freshly brewed batch of coffee immediately after brewing. A user may take a reading of the TDS % of the coffee from the display of refractometer **1000**. The user may then manually input the TDS % reading into coffee design application **602** of IHS **600**. In response, coffee design application **602** displays the actual TDS % and extraction on the plotted brew line of a universal brew line chart such as seen in FIG. **5**. In an alternative embodiment shown in FIG. **10**B, refractometer **1000** couples to, or otherwise communicates with IHS **600**. In this manner, refractometer **1000** reads and supplies TDS % data to coffee design application **602** of IHS **600** without manual user intervention.

FIG. **11**A is a flowchart that depicts process steps for configuring refractometer **1000** to determine the total dissolved solids (TDS) % of a brew coffee sample. To use refractometer **1000** to measure the total dissolved solids (TDS) of coffee or any other liquid, refractometer **1000** should be both calibrated and correlated. The calibration of a refractometer is performed by measuring the index of refraction of distilled pure water at a specific temperature to ensure that the refractometer is measuring index of refraction properly. The correlation of a refractometer is the conversion of the measured index of refraction to a scale of interest to the end user. Typically, refractometers have software that correlates to a BRIX scale. In that case the software assumes that the index of refraction of the liquid presented to the refractometer corresponds to a sugar-water solution and will output a BRIX value (equal to the % sugar by weight in solution) based upon the measured refractive index. Unfortunately, for most other liquids, such as coffee, a BRIX scale is not valid and can lead to erroneous results.

To configure refractometer **1000** to measure the TDS of a brewed coffee sample, process flow commences at start block **1105** in the flowchart of FIG. **11**A. A user or other entity first calibrates refractometer **1000**, as per block **1110**. The calibration of refractometer **1000** is performed in the conventional manner by measuring the index of refraction of distilled pure water at a specific temperature to ensure that the refractometer is measuring index of refraction properly.

To correlate refractometer **1000** for coffee, the change in index of refraction with TDS as well as temperature is determined. The user or other entity begins correlation of refractometer **1000**, as per block **1115**. One exemplary and preferred method of determining the TDS of a coffee solution is through a dehydration method. To start the correlation procedure, different batches of coffee are brewed at different brew concentrations, while maintaining approximately the same extraction percentage from the selected batch of roasted and ground coffee beans, as per block **1120**. In other words, the user or other entity brews multiple coffee samples with different respective coffee concentrations in terms of total dissolved solids (TDS) %. The extraction percentage set during the refractometer correlation procedure is preferably the extraction percentage chosen as that of an ideal coffee solution for consumption. For purposes of example, the extraction percentage is 20%±1% although it is possible to employ other extraction percentages if desired depending on the application and user preference. For an accurate correlation procedure, it is preferable that the extraction percentage remains approximately constant because coffee grinds are composed of a mix of different materials that have different water solubility rates. The materials that have a high water solubility rate are extracted first from the coffee grinds and give the coffee a sweet flavor. Those materials that have a lower water solubility rate are extracted later in the brewing process and give the coffee a bitter flavor. Each of these different materials contained within coffee affect the index of refraction of water differently when they dissolve into it. Therefore for accurate correlation of the index of refraction of coffee to TDS, it is preferred that the extraction percentage is kept approximately constant. Note further that during the described correlation procedure it is preferred that the coffee used to make the different batches of coffee concentrations are from the same green and roast batch, and further, that they are ground to the same grade. For example, all-purpose universal Drip Grind would be derived of 8% Numbers 10/14 sieves, 65% Numbers, 27% Pan for a nominal particle size of 775 Microns (1 Micron-0.001 mm), according to the North American Coffee Industry Norms as published by Modern Process Equipment, Inc.

If required, a separate correlation procedure can be conducted for each coffee bean of interest and/or different degrees of roast to determine refractometer correlation equations for these bean and roast changes. For the brew concentrations that have the same extraction percentage, it is preferred that they encompass the range of TDS expected for the consumable coffee of interest. By way of example, the brew samples can span a 0.8% to 4.0% TDS range, since 1% to 1.5% TDS represents the typical range for coffee, and 3% to 4% represents the typical range for ice coffee concentrate. For expresso, the brew concentration of 2 to 6% TDS is typically of interest with the TDS range of 4 to 5% being preferable. For expresso, given that it contains a certain percentage of undissolved solids, these solids would need to be filtered before following the dehydration procedure outlined below.

Samples of each brew concentration are allowed to cool in respective sealed vial, as per block **1125**. Refractometer **1000** then measures not only the index of refraction of the sample but also the temperature of the sample. More particularly, refractometer **1000** measures the index of refraction (n_s) for each brew concentration sample across a range of temperatures as per block **1130**. For the correlation of refractometer **1000** for use outside of the brewing machine itself, a temperature range corresponding to ranges of ambient room temperatures are preferred such as 20 to 30° C. and index of refraction measurements can, for example, be taken in 1° C. increments. For a refractometer **1000** to be used to measure the index of refraction of coffee after it is brewed, the desired temperature range may be 70 to 90° C. with measurements taken every 2° C. as part of the correlation process. These correlation measurements are useful to derive the thermal dependence of the index of refraction for a specific brew concentration (i.e., a specific TDS).

To determine the TDS of each of the brew concentrations, containers (for example, glass beakers) are marked and weighed (preferable to an accuracy of 1 part in 1000 or better), as per block **1135** (1^{st} weight reading). Portions of each brewed coffee solution are poured into individual containers (not shown) and the filled containers are reweighed (2^{nd} weight reading), as per block **1140**. The filled containers are then placed into a dehydration oven, as per block **1145**. After the solutions have been dehydrated or desiccated, the containers are allowed to cool in a dry environment in order to prevent any subsequent moisture absorption, as per block **1150**. The containers are then reweighed (3^{rd} weight reading) preferably in a dry environment, also as per block **1155**. From these three weight readings, the weight of the dissolved solids and the weight of the original solution is derived, and therefore the TDS (equal to the ratio of these two measurements) is derived.

In more detail, assuming eight brewed samples of coffee of different TDS spanning 0.8 to 4.0% and ten temperature readings per sample, 80 data points are thus provided that map a three-dimensional space in TDS, temperature and refractive index. Taking TDS as the dependent variable, the TDS surface plot as a function of temperature and refractive index can be curve fit to find an equation that expresses TDS as a function of index of refraction (n) and temperature (T), (i.e. f(n, T)) as per block **1160**. Generally speaking, the curve fit of such data will be suitably fit by a linear function in index of refraction and a quadratic function of temperature. Curve fitting methods such as least squares, gradient descent, and others methods may be used. See for example, C. Daniel and F. S. Wood, *Fitting Equations to Data: Computer Analysis of Multifactor Data*, (John Wiley & Sons, NY, N.Y.), 1980]

The TDS formula for a fixed temperature T_0 is given by EQUATION 9 below:

$$TDS(n, T_0) = \frac{[n(T_0) - n_0(T_0)]}{C}, \qquad \text{EQUATION 9}$$

where n_0 is the index of refraction at which the curve fit indicates that the TDS is zero. Note that n_0 may not necessarily correspond with the exact index of refraction measured for pure water. Assuming that the range of index of refraction and hence TDS is relatively small, such as is the case for normal coffee, the constant C can be approximated to be temperature independent. In order to adjust for temperatures, the thermal dependence of index of refraction should be taken into account. The thermal dependence of index of refraction n for a fixed TDS coffee solution is approximated by a quadratic equation in temperature T according to EQUATION 10 below.

$$n=n_0+a(T-T_0)+b(T-T_0)^2 \quad \text{Equation 10}$$

where a and b are constants derived from the curve fitting of data and the index of refraction equation is expressed such that at $T=T_0$, the index of refraction is equal to n_0.

To the first order, the TDS formula that takes into account both index of refraction and temperature. for coffee is given by EQUATION 11 below.

$$TDS(n,T)=\frac{\left[\begin{array}{c} n-n_{01}-a_1(T-T_0)- \\ b_1(T-T_0)^2 \end{array}\right]}{C_1} \quad \text{EQUATION 11}$$

where n_{01}, a_1, b_1, and C_1 may be slightly different from the constants n_0, a, b, and C_1 of EQUATIONS. (3) and (4) depending upon the data fit.

Although EQUATION 11 may be used, for a more accurate fit of the data, particularly for higher values of TDS, it is preferred to fit the data to a full quadratic in both index of refraction n and temperature T. Although such a quadratic equation can be expressed in multiple forms that are essentially identical from the standpoint of a refractometer's electronics and/or software calculating the result, a convenient form, from the standpoint of person reading the equation is given by EQUATION 12 below.

$$TDS(n,T)=\frac{\left[\begin{array}{c} n-n_{02}+d_2(n-n_{02})^2- \\ a_2(T-T_0)-b_2(T-T_0)^2+ \\ e_2(n-n_{02})(T-T_0) \end{array}\right]}{C_2} \quad \text{EQUATION 12}$$

since the TDS is referenced to a control temperature T_0 and the index of refraction of n_{02}, which is substantially equal to the index of refraction of pure water at a temperature T_0, but may deviate slightly depending upon the empirical fit of the data in the index-temperature parameter space of interest. A formula such as the one represented in EQUATION 11 or 12 is programmed into the firmware **1085** or electronics of refractometer **1000** to correlate refractometer **1000** for the liquids (e.g., coffee), concentrations, and temperatures ranges of interest. In other words, the formula of either EQUATION 11 or 12 is programmed into, installed or otherwise stored in firmware **1047** of microcontroller **1045** in refractometer **1000**, as per block **1160**, for use in determining TDS of a particular coffee brew sample from index of refraction data and temperature data that refractometer **1000** provides. Storing the TDS formula of EQUATION 11 or 12 in refractometer **1000** in this manner completes the correlation of refractometer **100** for coffee solutions of interest. In EQUATION 11, TDS (n,T) varies linearly with index of refraction, but is a quadratic function of temperature. EQUATIONS 11 or 12 provide respective polynomial expressions that approximate or represent TDS(n,T). In EQUATION 11, TDS (n,T) varies linearly with index of refraction but is a quadratic function of temperature. EQUATION 11 provides a polynomial expression that approximates or represents TDS (n,T). In EQUATION 12, TDS (n,T) varies as a quadratic function of index of refraction and also as a quadratic function of temperature. EQUATIONS 11 and 12 both provide a polynomial expression that approximates or represents TDS(n,T).

It should be noted that the previously cited equations are at a specific measurement wavelength since index of refraction of all materials, including coffee, will vary with the incident wavelength. Typically this wavelength is at or near the Sodium D line of 589 nm. However, other fixed wavelengths are acceptable as well.

It is also noted that different coffee varieties, different degree of roasts, different levels of extraction during brew, extraction temperatures, and other brew variables can all affect the correlation to a small degree, such that some correlations of refractive index to brew solids may result in a better fit for darker versus lighter roasts. Separate scales for each range of degree of roasts may be correlated using Agtron or similar methods for determining the degree of roast.

Microcontroller **1045** uses temperature sensor **1050** to determine and/or set the temperature of both the prism **1015** and the sample **1020**. Although not shown in FIG. **10**A, microcontroller **1045** may control a resistive heater and thermo-electric cooler designed to bring the sample touching the prism face to a desired temperature. Since index of refraction changes with temperature and typically in a non-linear fashion, it is desirable to compensate for temperature effects. As such, in the design of the refractometer **1000**, it is desirable that the angles of incidences of the illumination beam at the entrance face of the prism and of the reflected beam at the exit face be minimized or at least compensated thermally since refraction at these interfaces will be a function of temperature. Likewise, the focal lengths of illumination lens **1010** and collection lens **1030** are a function of wavelength and to thermally compensate the temperature-dependent optical power, the lenses are preferably mounted to a mechanical mount whose thermal expansion compensates for the changes in the optical power of the lenses. Residual thermal changes to the refractometer's ability to measure index of refraction can be compensated using a lookup table based upon the readout of the temperature sensor **1050** that adds a correction factor to the critical angle detected by the refractometer.

To increase the resolution of refractometer **1000**, the operating index of refraction range can be reduced and the number of detector pixels increased. Above, as a clarifying example, a refractometer was described that worked for a range of sugar solutions of 0 to 10° BRIX using an Eastman Kodak KLI-2113 linear CCD with 2098 pixels. The resolution for this example was stated as 1.4E-5 in index of refraction and 0.0095° BRIX. If instead, an Eastman Kodak Model KLI-8023 linear CCD having a length of 8002 pixels and the BRIX scale desired were reduced to 0 to 5° BRIX, the resolution can be improved by a factor of 7.6 to 1.8E-6 in index of refraction and 0.0013° BRIX. In an alternate embodiment the linear detector is not increased in size and in fact may be reduced in array size. To achieve a higher resolution the detector is scanned along the beam produced by illumination lens **1030** in order to locate the beam intensity transition point representing the critical angle. In order to properly read out the critical angle, the scanning detector should be mounted to an encoder to that its position is known.

FIG. **11**B is a flowchart that describes process steps that refractometer **1000** employs to take a TDS reading for a brewed coffee sample. Process flow commences at start block **1170**. The user or other entity may calibrate refractometer **1000**, as per block **1172**. The user or other entity may place a brewed coffee sample in refractometer **1000** for the purpose of taking a TDS % reading via index of refraction measure. Refractometer **1000** takes an index of refraction reading of the brewed coffee sample, as per block **1176**, under the control of firmware **1047**. Microcontroller **1045** reads data from the light received by linear detector **1035** to determine the index of refraction of the brew coffee sample. In one embodiment, microcontroller **1045** of refractometer **1000** takes a temperature reading of the prism-sample interface **1034**, as

per block **1178**. Refractometer **100** provides automatic temperature compensation for index of refraction readings of brew coffee samples, as per block **1180**. Refractometer **1000** accesses the TDS formula of EQUATION 11 or 12 that firmware **1047** or memory **1049** stores to determine the TDS % of the brewed coffee sample, as per block **1182**. Refractometer **1000** displays the determined TDS % for the brewed coffee sample on refractometer display **1060**, as per block **1184**. Conveniently, refractometer **1000** provides a TDS % reading directly to the user via display **1060**. Refractometer **1186** then sends the determined TDS % to coffee design application **602** in information handling system **600** for display on the universal brewing control chart, as per block **1186**.

As discussed above, refractometer **1000** includes a network interface **1065** that couples to the Internet either by wire or wirelessly, and that may also coupled to another IHS **600** either by wire or wirelessly. In this manner, IHS **600** or another IHS on the Internet may provide updating to onboard firmware **1047** in refractometer **1000**. Refractometer **1000** may also receive updated or new scales via the Internet or IHS **600** in this manner. Refractometer **1000** may employ a wired or wireless connection to send information and data to coffee design application **602** in IHS **600** in this manner.

Those skilled in the art will appreciate that the various structures disclosed can be implemented in hardware or software. Moreover, the methodology represented by the blocks of the flowcharts of FIG. **9**A-**9**B may be embodied in a computer program product, such as a media disk, media drive or other media storage such as computer program product medium **608** of FIG. **6**A.

In one embodiment, coffee design application **602** implements the disclosed methodology as a set of instructions (program code) in a code module which may, for example, reside in the system memory **620** of IHS **600** of FIG. **6**A. Until IHS **600** requires this set of instructions, another memory, for example, non-volatile storage **645** such as a hard disk drive, or a removable memory such as an optical disk or floppy disk, may store this set of instructions. IHS **600** may also download this set of instructions via the Internet or other computer network. Thus, a computer program product may implement the disclosed methodology for use in a computer such as IHS **600**. In such a software embodiment, RAM or system memory **620** may store code that carries out the functions described in the flowchart of FIG. **9**A-**9**B while processor **610** executes such code. In addition, although the various methods described are conveniently implemented in a general purpose computer selectively activated or reconfigured by software, one of ordinary skill in the art would also recognize that such methods may be carried out in hardware, in firmware, or in more specialized apparatus constructed to perform the required method steps. In the context of this document, a computer program product or computer-readable medium may be any medium that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer-usable medium may include a propagated data signal with the computer-usable program code embodied therewith, either in baseband or as part of a carrier wave. The computer usable program code may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method of determining the total dissolved solids (TDS) in brewed coffee, comprising:

providing a brewed coffee sample to a coffee refractometer;

determining, by the coffee refractometer, the index of refraction (n_s) of the brewed coffee sample;

determining, by the coffee refractometer, the temperature of the brewed coffee sample to provide temperature compensation to the coffee refractometer; and

accessing, by a processor in the refractometer, a memory store in the refractometer, the memory store including a TDS formula that expresses the TDS of brewed coffee as a function of the index of refraction (n_s) of brewed coffee and the temperature of brewed coffee, to determine the resultant TDS of the brewed coffee sample.

2. The method of claim **1**, wherein the TDS formula expresses TDS as a linear function of index of refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample.

3. The method of claim **1**, wherein the TDS formula expresses TDS as a quadratic function of index of refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample.

4. The method of claim **1**, wherein the coffee refractometer displays the resultant TDS of the brewed coffee sample on a display of the TDS.

5. The method of claim **1**, further comprising transmitting, by the refractometer, the resultant TDS to a coffee design application in an information handling system for display as an actual TDS value on a universal brewing control chart.

6. The method of claim **1**, further comprising reducing an index of refraction range of the refractometer from a first range to a second range that is smaller than the first range to effectively increase resolution of the refractometer.

7. The method of claim **6**, wherein the reducing spreads more index of refraction information across a surface of a photodetector in the refractometer.

8. The method of claim **1**, wherein the refractometer couples by wire or wirelessly to another information handling system to receive firmware upgrades therefrom.

9. A coffee refractometer comprising:

a prism for receiving a brewed coffee sample thereon to form a prism-sample interface;

a processor that controls a light source to provide incident light to the prism-sample interface, the prism-sample interface refracting light toward a photodetector that couples to the processor;

a temperature sensor, situated adjacent the prism-sample interface and coupled to the processor, that provides temperature information to the processor; and

a memory store, accessible by the processor, that stores a total dissolved solids (TDS) formula that expresses the TDS of brewed coffee as a function of the index of refraction (n_s) of brewed coffee and the temperature of brewed coffee, to determine the resultant TDS of the brewed coffee sample.

10. The coffee refractometer of claim **9**, wherein the TDS formula expresses TDS as a linear function of index of the refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample.

11. The coffee refractometer of claim **9**, wherein the TDS formula expresses TDS as a quadratic function of index of the refraction (n_s) of the brewed coffee sample and a quadratic function of the temperature of the brewed coffee sample.

12. The coffee refractometer of claim **9**, further comprising a display, coupled to the processor, that displays the resultant TDS of the brewed coffee sample.

13. The coffee refractometer of claim **8**, further comprising a network interface coupled to the processor that transmits the resultant TDS to a coffee design application in an information handling system (IHS) for display as an actual TDS value on a universal brewing control chart.

14. The coffee refractometer of claim **9**, that reduces an index of refraction range of the refractometer from a first range to a second range that is smaller than the first range to effectively increase resolution of the photodetector.

15. The coffee refractometer of claim **14**, wherein reducing the index of refraction range of the photodetector spreads a smaller range of index of refraction information across a larger surface of the photodetector.

16. The coffee refractometer of claim **13**, wherein the network interface couples by wire or wirelessly to another information handling system to receive firmware upgrades therefrom or output readings in response to requests for measurements automatically another information handling system.

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